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THE PSEUDOSUCHIAN REPTILE TYPOTHORAX MEADEI

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ABSTRACT—The osseus anatomy of *Typothorax meadei* n. sp. is described from new and relatively complete material collected in the Dockum Triassic deposits of Texas. Anatomical data show this reptile to be a pseudosuchian noticeably more specialized than the European form *Aetosaurus* but less advanced in spinescence than the American genus *Episcoposaurus*.

Relations with allied animals are discussed, the comparisons suggesting that the American Upper Triassic pseudosuchians represent a nearly terminal phase in the evolution of the group.

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INTRODUCTION

PROMINENT in the Dockum deposits of Texas are spinescent reptiles superficially resembling the alligator in form and size but comparable to the extinct group Pseudosuchia in anatomical characters. American representatives of this suborder were found in the western Triassic formations by Cope and first reported in 1875 from New Mexico and in 1887 from Texas. Both of the genera were described from a small amount of material, some of which is of doubtful association. Recently discovered Texas remains forming the basis for the descriptions to follow are most comparable to the animal found in New Mexico, having characteristi-

cally sigmoid femora and dermal plates resembling those of the type of *Typothorax coccinarum* upon which the genus *Typothorax* was based. Another closely related form, *Episcoposaurus haplocerus* Cope, 1887, represents a larger reptile with more completely developed dermal armor. *Desmatosuchus spurensis* Case, 1921, described from more complete material, is probably generically identical with *Episcoposaurus*. The structure of the skulls of both *Typothorax* and *Episcoposaurus* is definitely pseudosuchian, and other features of the anatomy show the crocodiloid characters of the group; these were noted in connection with the form of the armor by the earlier workers, and revision of Cope's types by von Huene (1915) suggests such affinities with other parts of the postcranial skeleton.

The associated remains of two relatively complete specimens of *Typothorax* in the University of Texas collections were found 3 miles north of Otis Chalk, Howard County, Texas. These are supplemented by fragmentary remains from other localities as the sources of data for the anatomical study. Specimen no. 31185-84a[1] consists of a fragmentary skull, a poorly preserved vertebral column, appendages, and dermal armor susceptible of reconstruction from the anterior cervical region to the proximal caudal. Associated with this specimen were numerous small dermal buttons and plates referable to the ventral and appendicular armor. Specimen no. 31185-84b includes a fairly complete skull, portions of the nuchal plates missing in 31185-84a, fragments of dorsal plates, an incomplete vertebral column, the major limb bones, and fragmentary remains of the pectoral and pelvic girdles. These two specimens are designated as syntypes. Of the less complete materials collected in the Otis Chalk region is no. 31100-435 consisting of the posterior two-thirds of the tail of *Typothorax*. Also included are no. 31098-29, spine-bearing plates probably of the third and fifth neck segments and miscellaneous plates of *Typothorax* sp., and no. 31100-257, median plates with conical eminences referable to *Typothorax coccinarum*.

Most of the bone was well preserved but parts of a few elements had been destroyed by gypsum "rotting" or weathering and the action of soil acids. Matrix was removed by dental tools, grinders, and acid etching. The specimens were surrounded by layers of clay-ironstone, hematite or limonite inclusions in calcite. Quarry and laboratory charts were made only for portions of the more complete skeletons, but measurements of the elements and assembly of a mounted specimen permitted a fairly accurate restoration of the remains. This restoration (plate 34) is a composite based on the skull of no. 31185-84b, the appendicular, axial skeleton and armor of no. 31185-84a and the tail from no. 31100-435. Case's restoration and description of *Desmatosuchus* were helpful in establishing the pattern of the dermal armor and the vertebral sequence. Features restored without a basis of fact include the rostral region of the skull, portions of the proximal caudal armor, and the pelvic girdle. Appendicular and abdominal plates are not represented.

I am indebted to Dr. E. H. Sellards of the Texas Memorial Museum for permission to study the specimens. Field and laboratory assistance of Mr. Powell Goodwin resulted in the collection of valuable material and the assembly of the museum specimen. The illustrations were ably prepared by Lois Chambers Taylor. Grants from the University of Texas Research Institute and the Penrose fund of the Geological Society of America provided financial aid for field work and illustrations.

The species is named *Typothorax meadei* in honor of Dr. Grayson Meade, who collected the principal specimens.

GENERAL FEATURES OF THE SKULL

The skull (figs. 1, 2) is short rostrally, the length of the mandibles indicating a short snout. Insculpted antorbital vacuities, the anterior and lateral position of the external nares, and the presence of lateral vacuities in the mandibles are pseudosuchian characters. Modification of the posterior portion of the skull table in the development of crescentic abutments for the nuchal armor, the edentulous anterior region of the jaws, and the descending process of the jugal constitute the most apparent divergence from the primitive pseudosuchian pattern.

Evidence is lacking as to the lower struc-

[1] University of Texas Collection number. Specimens in Texas Memorial Museum, Austin, Texas.

FIG. 1—*Typothorax meadei* Sawin, n. sp. Skull in dorsal, palatal and lateral views, ×0.4, Univ. of Texas no. 31185-84b. The quadrate flange of the pterygoid is removed on the right side of the palatal view. Restored areas shown in diagonal lines.

ture of the temporal arcade, and it is possible that only a single upper fenestra was present. There is also uncertainty as to the extent and position of the post-temporal fenestra. Distortion and fracture in the region of the quadrate prevents a complete description of the region. One quadrate with an attached portion of the quadratojugal has no contact with the skull, but lines projected from the squamosal and the quadrate process of the pterygoid show the quadrate to be probably in a fixed position. Badly crushed portions of the palate when assembled were found to be generalized in form and comparable to those of other pseudosuchians. Only a part of the quadrate ramus of the pterygoid was preserved; the basipterygoid processes and the posterior portion of the palatine process are missing, as are the anterior portions of the prevomer and the ethmoidal region. The pterygoid has a well-formed descending process, and a small vacuity is present anterior to the transpalatine. Sculpture patterns of the skull roof are obscure, and growth zones are difficult to detect. Paired centers of ossification are present centrally in the parietal region, taking the form of prominences. These are finely sculptured with small central pits radiating to a peripheral zone of coarser pits. The area between the orbits and the nares is elongated, but the poorly preserved surface shows no definitely marked sculpture suggestive of intensive growth.

The dentition consists of bluntly conical marginal teeth. Seven occupy the posterior two-thirds of the precoronoid region of the mandible and nine or ten are marginally placed on each maxilla. Three smaller teeth were found on a fragment of the premaxilla, and it is probable that a complete series was present with a small gap between the maxillary and premaxillary as in other pseudosuchians.

The slipper-shaped jaw is short with a long symphysial region extending from the pointed distal end nearly to the mental angle. More than the anterior third of the upper surface of the dentary is edentulous. It is probable that this region was covered by a horny beak. Seven teeth, 0.5 cm. in diameter at the base, occupy the central portion of the dentary to form the functional tooth row.

The coronoid region is deep with a large lateral vacuity bounded above by the coronoid, below and in front by the angular, posteriorly by the surangular. This opening is confluent with the meckelian fossa, which extends forward to the end of the tooth row. Other apertures include the mental foramen centrally placed above the mental angle and a small lateral opening at the tip of the jaw. There is a well developed retroarticular process whose mesial border has a poorly preserved dorsally extended process.

DERMAL BONES OF THE SKULL ROOF

Premaxilla.—This bone is represented by only a small fragment, but a groove on the upper distal surface of the maxilla shows the probable extent of overlap. Small teeth are on the preserved fragment, but the distal end may have been beaked to conform with the edentulous tip of the mandible.

Maxilla.—This element extends from the rostral region to the jugal, forms half the posterior and ventral borders of the naris and the anterior and ventral border of the anteorbital fenestra. It is overlapped by the premaxilla over the anteroventral border of the naris and is produced behind the narial rim to meet the nasal dorsally and the lacrimal posteriorly. It is overlapped by the anterior portion of the jugal beneath the posterior rim of the anteorbital fenestra. Nine bluntly conical teeth, four or five of which were in place, comprise the dentition. On the outer surface the dorsal process is insculpted in front of the anteorbital opening and four or five nutrient foramina are in a line about 1 cm. above the ventral margin. No definite sculpture is apparent on the outer surface of the bone. Mesially the bone is as thick as the dental surface to a point a little below the narial rim. Here the surface slopes outward and upward to the thinner dorsal process.

Jugal.—The jugal overlaps the maxillary in front, meets the lacrimal dorsolaterally, and gains a brief contact with a thin spur of the prefrontal in the middle. Posterodorsally it forms two-thirds of the thin ventral rim of the orbit. A broken surface of the bone directed toward the postorbital region was probably continued as shown in figure 1. Ventrally the outbowed, posteroventrally directed process of the jugal tapers to a

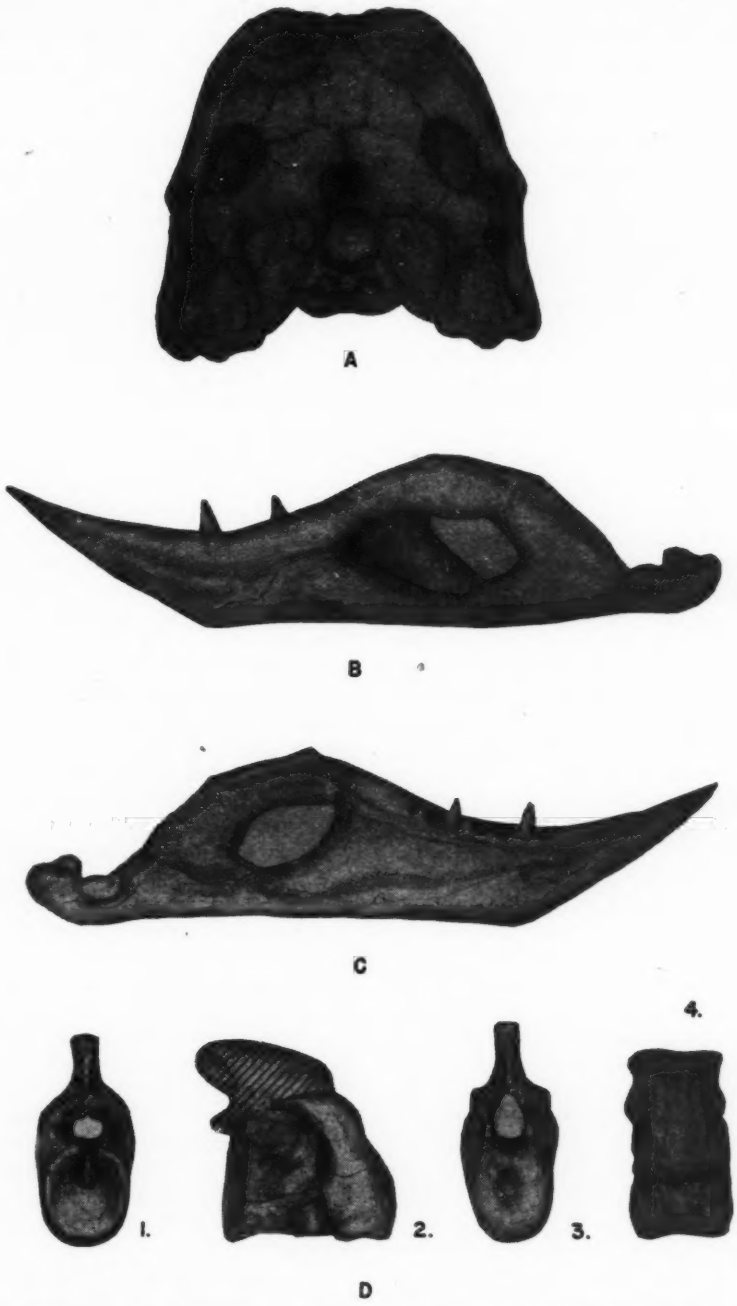


FIG. 2—*Typothorax meadei* Sawin, n. sp. *A–C*, Univ. of Texas no. 31185-84b, ×0.4. *A*, Skull in occipital view; *B*, jaw, lateral view; *C*, jaw, mesial view. *D*, *1–4*, Anterior, lateral, posterior and ventral, views of atlas and axis Univ. of Texas 31185-84a, ×0.4.

point, which may have had an overlapping junction with the quadratojugal. Mesially the topmost portion of the jugal forms a stout abutment for the transpalatine, this thicker region of bone extending ventrally to the maxillary. The bone is excavated beneath the junction with the transpalatine, and a pit is present on the ventral surface at the junction with the maxilla. The outer suborbital area is gently concave, sloping laterally to a longitudinal ridge, which extends along the jugal process. The outer surface is smooth.

Parietal.—The parietal meets the frontal at an irregular sutural border on a line across the middle of the orbits. This suture extends diagonally backward and ventrally, where the bone tapers irregularly between the postfrontal and the posterior surface of the postorbital bar. Here the parietal forms more than half of the anterior margin of the upper temporal fenestra and presents a broad, slightly concave surface within the fenestra facing posteroventromesially. Posteroventrally the parietal extends onto the occiput to meet the postparietal and posterolaterally it meets the "tabular" region. No parietal foramen is present. Each element is elevated centrally, small pits and ridges radiating from the elevation.

On the ventral surface the central portion of the bone is slightly concave dorsally above the cerebellar region of the braincase. Behind and on the sides it forms the thick (1.30–1.60 cm.) abutment for the supraoccipital and otic regions of the braincase.

Tabular.—It is possible that the element here described is really a portion of the parietal, but in both specimens the articular surfaces for the nuchal armor and the bone posterior and lateral to them appear to be separated from the parietal suturally. Distortion of one of the specimens and poor preservation in the other, however, leaves a reasonable doubt as to the status of the tabular as a separate element. The tabular region is bordered anteriorly by the parietal, which it meets in front of the articular surface for the nuchal armor. As seen dorsally this surface is semiovate in outline with the anterior surface merging with a slightly elevated ridge at the dorsal border rim of the occiput. Laterally the articular surface is confluent with the dorsally flattened down-curving posterior rim of the upper temporal opening. Posteriorly and mesially the stout ventral portion of the articular region is slightly incurved from the flat upper border to merge with the sloping occipital surface. Mesially and ventrally the surface of the tabular beneath the articular region meets the postparietal. Posterolaterally the tabular region is continued as a broad, slightly concave surface, which forms the upper border of the post-temporal fenestra; ventrolaterally it tapers to join the squamosal. This area is bordered laterally by the dorsally flattened rim of the bar posterior to the supratemporal fenestra.

On the under surface the tabular and the parietal are deeply excavated to form an overhanging ledge beneath the dorsal rim of the supratemporal fenestra, both bones here overlying the opisthotic region of the braincase.

Postparietal.—This large median element is semicircular. It forms a superficial dermal face overlying the occiput dorsally and laterally from an irregular line across the upper rim of the foramen magnum to both parietal and tabular regions. It overlies the supraoccipital and the mesial surfaces of the paroccipital processes; laterally it forms the dorsomesial rim of the post-temporal fenestra. The surface is distorted, but rugosities for muscle attachments are present on the ventrolateral portion of the bone.

Nasal.—This elongate element is incomplete in front, where it evidently extended to a junction with the premaxilla. It forms the dorsal and posterior rim of the large narial opening and is overlapped behind by the frontal at an irregular suture. Anterolaterally it joins the dorsal process of the maxilla and posterolaterally the lacrimal, the suture with the maxilla being twice the length of that with the lachrymal. A shallow groove modifies the dorsal surface, curving inward from the posterolateral surface of the bone to become indistinct as it approaches the midline at the anterior third of the length.

The under surface of the nasal region is concave dorsally. A longitudinal spur extends mesially from the maxillo-lacrimal suture to form a groove continuous with a similar structure of the lacrimal. Anteriorly the spur extends beyond the posterior rim of

the naris and may have formed a portion of the base for a fragile septomaxillary. The latter is not preserved in the specimens.

Lacrimal.—This bone forms the posterior and upper two-thirds of the insculpted anteorbital fenestra and a small section of the anteroventral rim of the orbit. It meets the nasal anterodorsally, the prefrontal posterodorsally; posteriorly it sends tapering overlapping processes over the jugal and maxilla, and anteriorly it abuts against the dorsal process of the maxilla. The lacrimal foramen is situated close to the outer rim of the orbit on the suture with the prefrontal.

Laterally the bone forms the major portion of the thick preorbital bar, which is triangular as seen in section. A rough but unsculptured area extends peripherally from the depressed anteorbital region. The lacrimal duct probably underlies the upper border of these two surfaces.

Posteromesially the surface is concave; anteriorly at the mesial border of the anteorbital fenestra the lacrimal forms a shelf which underlies a deep groove. This groove follows the sutural borders of the lacrimal with the nasal and is continuous in front with the nasal groove and behind with the groove along the prefrontal-frontal suture.

Prefrontal.—This bone forms the broad anterodorsal rim of the orbit and tapers to a point between the lacrimal and the frontal nearly to meet the nasal at the foremost point. Posteriorly within the orbit it becomes expanded as a thin preorbital wall. Here with the lacrimal it partly encloses an almost hemispherical space above and behind the anteorbital fenestra. A troughlike groove extends along the ventral border with the frontal and bifurcates at half the length of the lacrimal. The principal part of the groove extends along the nasomaxillary suture to the posterior rim of the naris; a subordinate groove extends mesially on the frontal and ends near the nasofrontal suture.

Frontal.—The frontal overlies the skull roof from the middle of the anteorbital to the postorbital region. It meets the nasal at a sigmoidal sutural interval anteriorly, the lacrimal anterolaterally and the prefrontal laterally. Posterolaterally it forms the thick dorsal rim of the orbit and extends to the postfrontal. Posteriorly it joins the parietal.

The dorsal surface has sculpture of longitudinal pits and ridges radiating forward from a group of deep undistorted pits centrally placed on the posterior quarter of the length. A rugose irregularly pitted area of the posterolateral region above and behind the orbital rim may have formed the base for a horny spine.

The under surfaces of the frontals form a central concavity bordered laterally by a ridge. This descends abruptly into a deep lateral groove at the sutural border with the prefrontal. It is possible that the mesial portion of the ridge formed the limits for the expanded anterior portion of the braincase.

Postfrontal.—This small, thick, crescentic element forms the heavy posterodorsal border of the orbit. It is overlapped extensively by the ventral process of the parietal. Ventrally it joins the postorbital at an irregularly interdigitate sutural border. Ventromesially it forms the thick (1.8 cm.) orbital rim and mesially it slopes to the apex of the postorbital bar, which is triangular as seen in section. Dorsomesially this sharp border bifurcates to limit a concavity which is lateral to the most expanded portion of the braincase at the dorsal limits of the ridge between the prootic and the laterosphenoid.

Postorbital.—This element is distorted and incomplete ventrally. It probably formed the posteroventral rim of the orbit and provided a junction between the jugal and squamosal as shown in figure 1.

Squamosal.—The preserved portion of this bone is comparable to that of lizards. Laterally it is convex with a central longitudinal ridge sloping downward and forward from the dorsal process, which joins the tabular (or parietal). Anteromesially it overlies the paroccipital process and posteromesially it is excavated to accommodate a disc-shaped intercalated element, which is apparently an independent ossification. In the specimen this region is distorted, the posterior portion of the quadrate flange of the pterygoid being crushed against the ventral portion of the squamosal.

Quadrate.—The major portion of the right quadrate was found in articulation with the mandible but had no contacts with the occiput. It is possible that it abutted against the squamosal, paroccipital process, and quadrate flange as shown in figure 2. As seen posteriorly the central portion of the bone is

concave and expanded ventrally to the articular border from the incomplete apex. This probably joined the squamosal dorsally. A flange extends anterodorsomesially, ending in a fractured surface, which may have reached the posteroventral portion of the paroccipital process. The quadrate curves to a thin-edged lateral surface overlapped by the quadratojugal.

Quadratojugal.—A thin quadrilateral fragment was found overlying the lateral face of the quadrate and was evidently crushed and displaced from its original position. A doubtful contact was found with a similar fragment found loose in the matrix over the lateral region of the braincase. These possibly extended dorsally from the quadrate to the squamosal. The considerable distortion of the fragments and their doubtful relations prevent further analysis. Dotted lines show a possible restoration based on the pattern known for *Aetosaurus* as shown by Huene (1920).

DERMAL BONES OF THE PALATE

Vomer.—The vomer is a thin triangular bone joining the palatine posteriorly and forming a considerable portion of the mesial border of the internal naris. Both elements were broken at the median line and compressed laterally in the specimen.

Palatine.—This region is also distorted, but the junctions with the maxilla and pterygoid allow a fairly accurate restoration. The palatine joins the vomer in front and the maxilla on the sides. The junction with the latter occurs as a broad, thin plate sloping from a point opposite the last tooth alveolus forward and upward to a point on a line across the anterior third of the anteorbital fenestra and slightly above the level of its ventral rim. Posteriorly the palatine joins the pterygoid and posterolaterally it forms most of the mesial rim of the suborbital palatal vacuity.

Transpalatine.—This bone is a short, stout rod, oval in section, oriented dorsomesially, and expanded proximally where it abuts against the maxilla and jugal. Here it is overlapped slightly by the lacrimal. Dorsolaterally it is continuous with the surface of the anteroventral rim of the orbit. Proximally it expands to overlap the anterior portion of the descending process of the pterygoid; this expansion is convex dorsally and concave ventrally. The anteromesial portion of the rod forms the posterior border of the suborbital palatal vacuity.

Pterygoid.—Most of the front of the palatal process is preserved and part of the quadrate ramus is present behind. The entire basipterygoid region is missing, including the processes of the basisphenoid.

The palatal process joins the palatine with sutural relations interpreted as shown in figure 1. Centrally the bone is shallowly convex dorsally and produced ventrolaterally into a stout descending process, which is concave ventromesially and convex dorsolaterally. This process is covered in front by a thin spur from the transpalatine.

Quadrate ramus.—Only the posterior part of this ramus is preserved. Distally the bluntly rounded end is displaced in the specimen between the squamosal and paroccipital process. The bone is flat ventrally and slopes upward toward the basipterygoid region. Dorsomesially it is produced as a thin incomplete lamina, which closely approaches the braincase laterally and may have extended dorsally to reach the parietal. The ventroproximal part of the thin bone curves mesially below the anterior border of the proximal portion of the paroccipital process. The position of the quadrate ramus is uncertain due to the lack of data on the relative position of the quadrate with the basipterygoid process.

BRAINCASE

The front of the neural cranium is not preserved; the ethmoid and a part of the pleurosphenoid regions are missing. There is also a gap behind in the area at the base of the pleurosphenoids, caused by the fracture and loss of the basipterygoid processes.

As seen in lateral view, the brain case is remarkably deep behind on a vertical line through the center of the temporal fenestra. The considerable distortion of the anterior section of the basisphenoid in part conceals the upward curvature of the apposed pleurosphenoids. Since no sutures are determinable, the braincase is described by regions as follows:

Pleurosphenoid or laterosphenoid.—These thin elements probably surrounded the olfactory tracts and the cerebral hemispheres.

Together with the skull roof they form a cavity roundly triangular as seen in transverse section. This cavity expands posteriorly and ventrally. The thin ventral and posterior portion may have formed the dorsum sellae. Laterally the posterior border is distinguishable by a vertical crescentic ridge. Depressions presumably related to foramina for motor nerves of the eye are present on the anterior border of the ridge one-third of the height of the pleurosphenoids in this region. It is possible that the ridge represents a closed suture between the pleurosphenoids, the prootic region laterally, and the basisphenoid ventrally.

Prootic region.—The outer surfaces of this area are characterized by a hemispherical depression, which includes a large foramen for the trigeminal nerve posteroventrally. Anteroventral to this opening the braincase is incomplete, but a stoutly formed, elevated, rounded ridge extends above the basipterygoid region and upward in a direction suggesting a junction with the base of the crescentic ridge. Allowance for distortion further indicates such a junction. Posterior to the ridge and immediately above the basipterygoid region is a pit, which may mark the point of departure for branches of the facial nerve and the lower morphological border of the prootic.

Posterodorsolaterally the depressed area of the prootic grades into cancellous bone overlain by bone fragments. Centrally the contours merge with the backward curvature of the paroccipital process.

Opisthotic region.—The paroccipital process extends lateroposteroventrally, presumably to gain contact with the mesial region of the quadrate. It is expanded proximally to form the dorsoposterolateral wall of the braincase and is excavated ventrally, where two apertures are present; one is probably the fenestra ovalis, the other possibly an exit for the vagal group of nerves. This excavation is sharply delineated by the bifurcated ventral margins of the paroccipital. The anterior margin curves downward over a wide area and forward to meet the rounded ridge of the ventrolateral wall of the braincase in front of the seventh nerve exit. Posteriorly the margin is acutely curved ventroanteriorly and merges with the lateral rugosities of the basioccipital tubera.

Exoccipital region.—The exoccipital forms most of the margin of the foramen magnum, extending upward and forward as a pillar from the dorsolateral face of the condyle to meet the paroccipital process along a dorsomesially slanting suture. Two foramina in the place ordinarily occupied by the hypoglossal nerve occupy the lateral concavity between the exoccipital and the posterior margin of the paroccipital process. These openings are dorsoventrally placed; the lower foramen is slightly above a horizontal line projected from the suture of the exoccipital with the condyle, and the upper opening is 0.8 cm. dorsoposterior to it.

Supraoccipital.—The upper cartilage bone component of the braincase is well developed and, if this distorted region is correctly interpreted, forms the upper border of the foramen magnum. This region is covered by the postparietals.

Basal region—basioccipital.—Sutural borders of the basioccipital with the basisphenoid are not easily distinguishable but appear to be present at the posterior limits of the tubera. Contours are sharply defined at the base, a well-rounded upward curvature extending from the base of the condyle down to the rugosity of the tubera. Here the basioccipital expands to conform to the broad portion of the braincase below the opisthotic region. The posterior margin of the paroccipital process continues to the surface of the bone of the ventrolateral portion of the braincase to merge as an elevated surface with the anterodorsal ridge of the tubera.

Basisphenoid.—As previously noted, the anterior portion of this bone, including the basipterygoid processes, is missing. Posteriorly the surface is marked by two crescentic, deeply incised, rugose excavations with elevated margins, which form the tubera. These are separated behind by an interval of about 0.5 cm. and diverge anteriorly. Their mesial rims form the border for a deep median pit. The convex border of the tubera faces anteroventrally, the uppermost portion of the crescent dividing the ridge leading from the posterior margin of the paroccipital process. The median pit anterior to the tubera is distorted in both specimens. As noted by Case (1921) it is in the position of a similar pit in the alligator.

It differs in lacking a median septum and in the absence of openings for the eustachian canals. The anterior borders of the pit were probably in part formed by the posteriorly expanded margins of the basipterygoid processes, but most of the excavation extends upward about 0.6 cm. into the body of the basisphenoid.

Anteriorly two symmetrical broken surfaces show the position of the basipterygoid processes, which are restored and shown by dotted lines in figure 2.

MANDIBLE

Dentary.—As seen laterally the dentary (fig. 2) extends half the length of the jaw from its junction with the coronoid above the anterior third of the length of the mandibular fossa and tapers to a narrow triangular point distally. It meets the angular posteroventrally and the splenial anteroventrally, the sutural length with the latter being half the length of that with the former. The lateral surface is convex with small nutrient foramina placed near the alveolar border and a large groove and foramen near the distal end. The latter probably conducted nutrient vessels to the base of a horny beak. Dorsally the edentulous anterior half of the dentary is smooth, sloping dorsomesially and posteriorly; alveoli for seven teeth are present behind. Mesially the dentary meets the splenial anteroventrally and the prearticular posteroventrally, the suture with the latter extending along the alveolar border. Anteriorly over half of the mesial surface forms the symphysis; posteriorly the surface is deeply grooved for the mental foramen, which enters the jaw at the topmost portion of the splenial.

Splenial.—This bone forms the mental angle of the jaw and has a slight lateral exposure beneath the dentary-angular suture. Mesially it meets the dentary anterodorsally, the prearticular posterodorsally, and the angular posteriorly. The anteroventral portion of the bone forms a part of the symphysis, and the mental foramen lies dorsally beneath the end of the prearticular.

Coronoid.—The front end of this bone meets the dentary at an inter-digitating suture, and the rear end adjoins the surangular along an irregular border. Ventrally the coronoid forms the thin upper rim of the mandibular fossa. The lateral surface is convex; dorsally a short ridge is centrally placed, a rounded surface sloping downward anteriorly and posteriorly from it. Mesially the roundly convex dorsal border overhangs the thin ventral area above the mandibular fossa.

Surangular.—The surangular meets the coronoid anterodorsally, forms the posterior border of the mandibular fossa anteriorly, and meets the angular ventrally. Mesially it stoutly abuts against the lateral face of the articular and joins the prearticular at the posteroventral border of the meckelian fossa. This is excavated beneath its junction with the articular anteriorly. Posteriorly the surangular forms the lateral face of the retroarticular process. The dorsal border slopes down from the coronoid to the articular; the anterior three-fourths of the length of the border is flat, facing dorsolaterally and the posterior fourth slopes abruptly down to the articular and faces dorsoposteromesially.

Angular.—Anteriorly the angular tapers between the dentary and the splenial and posteriorly underlies the major portion of the retroarticular process. Laterally it forms most of the ventral border of the mandibular fenestra and posterodorsolaterally joins the surangular at a long shallowly sigmoidal sutural border. Mesially the angular has but a small exposure where it meets the prearticular along half of the ventral length of that bone.

Prearticular.—Dorsally this bone meets the alveolar border of the dentary from the second tooth alveolus to the anterior rim of the meckelian fossa. Centrally and dorsally it forms the mesial rim of the fossa and posterodorsally it joins the articular and covers most of the mesial portion of the retroarticular process. Anteroventrally it meets the splenial and posteroventrally the angular. Anteriorly the bone is vertically placed and flat; posteriorly it is convex, with a curvature adapted to the inflected part of the articular.

Articular.—This element forms the articular surface in front and most of the retroarticular process behind. Posteromesially a free-ending process extends dorsally behind the articular surface. The articular is enclosed laterally by the surangular, and

mesially by the prearticular. Ventrally the angular underlies half of the retroarticular region.

VERTEBRAE

The incompletely ossified vertebral column is more lightly built but structurally very similar to that described for *Desmatosuchus* by Case (1921). In the cervical region of nine or ten elements the vertebrae, with the exception of the axis, are anteroposteriorly compressed and more concave behind than in front. Posteriorly, in the dorsal series of 16 or 17 elements, the body of the amphicoelous centrum becomes longer, and in the caudal series of 24 or 25 elements quite elongate. Nine or ten vertebrae are missing in the thoracic series, and one sacral is absent. Preservation of the specimens is poor, and but few of the neural arches or rib articulations are to be found. Fortunately, most of the vertebrae were disposed in the matrix in such a way as to leave little doubt as to their linear arrangement.

The atlas and axis (fig. 2D, 1–4) were found in close articulation and were prepared as a unit. The atlas is half the length of the axis. The face of the centrum is fully concave in front. The lower third of the condylar articular surface is formed by the hypocentrum and the larger upper portion by the conjoined neural arches. A notch in the dorsal surface of the concavity corresponds to the odontoid process of the axis. Ventrally the centrum is rectangular in outline and flat with a shallow central concavity. Posteroventrolaterally rugose protuberances extend slightly outward to form articular surfaces for the first pair of cervical ribs. The neural arches are suturally related to the hypocentrum, the line of attachment running above the middle of the centrum as viewed laterally. The axis conforms to the shape of the atlas anteroventrally for one-third of its length then becomes laterally compressed behind the lower articular surfaces for the second cervical rib. Above and behind this surface at a level with the base of the neural arch the diapophysis is formed as a dorsally buttressed oval concavity. The body of the centrum is considerably depressed behind and between the rib facets. The rear outline of the centrum is ovoid with a dorsal notch for the nerve cord. The surface is covered in front by the atlas but it is evident that a well-developed odontoid was present, its tip being visible in an anterior view of the conjoined vertebrae.

The five succeeding cervical vertebrae (fig. 9) are similar in structure and differ in proportions as shown by the measurements. Variations in the pattern include a progressive elongation and expansion of the centrum and of the rib articular processes, the diapophysis enlarging to a disproportionate degree. The lateral concavity behind the rib facets also becomes more pronounced. Both the eighth and the ninth cervicals have considerably enlarged diapophyses, which are transitional in form between the cervical rib articular surfaces of the more anterior vertebrae and the transverse processes of the thoracic elements. The anterior face of the centrum is expanded in outline, the parapophysis protruding ventrolaterally. The centrum becomes more robust and the parapophysis, which is noticeably wider in the eighth vertebra, is structurally united with the transverse process in the first recognizable thoracic element. This union is effected by means of a sharp-edged ridge extending dorsally from the parapophysis to merge with the base of the prezygapophysis beneath the overhanging portion of the transverse process. Zygosphenes and zygantra are known in the posterior members of the series but are not preserved anteriorly.

Three elements are believed to be missing in the anterior thoracic series. The first thoracic vertebra sufficiently well preserved to merit description is probably the fifth (no. 14 in the series). The centrum is ventrally concave anteroposteriorly as seen in longitudinal section with the procoelous anterior end more expanded than the flattened, slightly concave posterior end. It is surmounted by a neural arch bearing a narrow neural spine with an irregularly expanded anteroventrally sloping tip. All of the articular surfaces are distorted, but it is evident that the zygapophyses were centrally situated, their margins exceeding but slightly the width of the centrum. The large proximally expanded and laterally extended transverse process has a nearly plane dorsal surface with a slight downward slope to the front. Its anterior margin curves regularly from the centrum back to the diapophysis.

Posteriorly the thin margin is indented lateral to the postzygapophysis. As seen in anterior view the surface beneath the prezygapophysis is concave, this depression extending laterally to the parapophysis. Above the latter the surface is excavated the length of the process. Posteriorly the bone is smooth and curves upward to an overhanging margin, which joins the upper portion of the postzygapophysis.

Posteriorly in the column the dorsal vertebrae have larger laterally compressed centra (fig. 14). The transverse processes are poorly preserved but appear to lack the angular displacement and the insculped anterior face of the anterior thoracic elements; the parapophyses are evidently in a nearly terminal position slightly mesial to the diapophysis. The neural spine is four-fifths the length of the centrum, bar-shaped in section, and has an irregularly expanded tip sloping downward from front to back.

The proximal caudal vertebrae are elongate with a length three to four times the central width. The face of the centrum is more concave and expanded anteriorly than posteriorly and conjoined paired articular surfaces for the chevrons face posteroventrally on the lower rim of the posterior end. Paired ridges bordering a central depression extend anteriorly from the anteroventral margins of the chevron articular surfaces as elevations on either side of the base of the centrum. The neural spines are shorter than those of the thoracic series and conform to the shape of the more elongate centrum. Changes in form and proportions of the remaining caudal vertebrae are shown in the restoration (fig. 13). It may be noted that of the preserved caudal series all but the last five to seven elements bear articular surfaces for the chevrons. One chevron, found dissociated from the column, evidently belongs to one of the more proximal vertebrae. This element has a crescentic proximal portion notched ventrally for the haemal canal. The latter is elongately oval in shape and is bordered laterally by narrow processes with a flat mesial and a slightly convex lateral surface. Ventrally these processes join to form a stout haemal spine, which is rounded anteriorly, keeled posteriorly, and tapered distally to a thin, rounded margin.

RIBS

All of the ribs are poorly preserved and dissociated from the vertebrae. Three types are apparent from the material, two based on the proximal portions of double-headed ribs probably referable to the left side of the posterior cervical or anterior thoracic regions; the other is probably a thoracic element and is known from 10 more or less completely preserved specimens.

The foremost member of the series is probably related to the sixth or seventh cervical vertebra. It is completely double-headed, the capitulum and tuberculum diverging as free processes at an angle of more than 45° and extending freely for a distance of about 2.5 cm. The articular surface of the tuberculum has nearly twice the area of the capitulum and is roughly quadrilateral in outline in contrast to the flattened oval shape of the capitular articular border. The mesial surface of the rib is flat with a convex inward curvature. Laterally a spinous projection extends outward from the lower portion of the tuberculum proximal to the point of bifurcation of the heads. It reaches distally to merge with the central portion of the neck of the rib.

The anterior thoracic fragment has an elongate tubercular process oval in section; when oriented to an anterior thoracic vertebra it extends mesially and a little anteriorly to meet the parapophysis. The cupped capitulum is superimposed on the angle of the rib where the thickness is greatest. The anterior surface is ridged laterally from the rim of the capitulum, the base of which is depressed at and beyond its junction with the shaft of the tuberculum. An overhanging ridge is developed from the convex surface of the tubercular shaft distal to the depression at the junction of the heads. The posterior surface is flat with a slight concavity at the junction of the heads, and the surface is sharply edged dorsally and rounded on the ventral side.

The most complete rib of the thoracic series (31185-84a #27) may be placed on the left side of the midthoracic region, where the vertebral articular surfaces are closely approximated. Here the parapophysis forms the anterior and less well developed articular surface. The articular surfaces of the tuberculum are not well preserved and the

capitulum is missing, but a definite curvature of the anteroproximal portion of the rib permits restoration. Laterally the surface is concave along more than the proximal third of the bone, this surface ending at the thin posterior margin. The central third of the rib is bladelike, with the posterior edge thicker than the anterior. Distally it becomes constricted above the terminal end, which is cupped for articulation with the costal cartilage.

A prominent spine is developed on the anteromesial surface of the rib at the base of the tuberculum. It extends to the proximal third of the bone's length, where it merges with the rounded anterior surface. The edge of the spine faces anteromesially to form the boundary for a longitudinal depression bordered in front by the curved surface leading to the capitulum. The posteromesial face is shallowly concave behind the spine; the central portion is slightly convex, grading into a concave surface above the constricted distal portion of the bone.

PECTORAL APPENDAGE

Scapulocoracoid.—The scapula and coracoid (fig. 3 A, B) are fused along a finely knit interdigitate suture well defined behind the glenoid fossa at the thickest portion of the bone. The blade of the scapula is poorly preserved peripherally, the bone probably terminating with a thin border along the upper two-thirds of the anterior and along the upper half of the length of the posterior edges. Laterally the blade is curved, with the greatest elevation slightly behind the center, the bone curving to form a sharp angle with the flat mesial surface. Beneath the blade the constricted thick neck of the bone curves ventromesially. This lower incurved section is massive. It is about 4 cm. thick centrally at the suture with the coracoid. The ventrolateral surface is gently concave centrally and has a spur of unfinished bone in front. An elevated oval protuberance delineates the concavity behind.

The surface in front is of poorly preserved unfinished bone lacking continuity with the blade. Posteriorly the relations of the oval protuberance with the supraglenoid region and the upper portion of the glenoid are apparent in the figures. There is no distinct supraglenoid buttress, the bone curving evenly to the rounded mesial face.

The scapular portion of the glenoid is subcircular in outline and faces posteroventrolaterally. Its diameter is 3.3. cm.; two-thirds of the area is flat, and the lower third curves downward to the coracoid portion of the glenoid. The latter faces dorsoposterolaterally, is ovoid in outline with its long axis (4.6 cm.) directed anterolaterally. Its principal curvature up to the scapular portion is in front of this axis.

The anterior half of the coracoid is poorly preserved, the thin remnants of the bone suggesting a bladelike anterior and anteroventral margin with a flat lateral surface and a concave ventral.

Posterolaterally the bone is incised beneath the glenoid. This surface is obscured by crushing but appears to be depressed to a considerable degree anterolaterally with rugosities on the thick ventrolateral region. Posteroventrally the coracoid is thick, with a surface of unfinished bone, which faces posteromesially. This surface may have joined a postcoracoid process, but none was recovered with the specimen. In *Sphenosuchus* such a process is fused to the mass of the bone (cf. Broom, 1927).

Humerus.—The humerus (fig. 4 A, B) differs noticeably from those of the phytosaurs in having a stouter shaft and more expanded terminal ends, the proximal width being greater than the distal. A stoutly developed deltoid crest is continuous with a flat preaxial surface, which is angularly delineated from the curvature of the shaft over two-thirds the length of the bone. Distally the upper angular surface of the preaxial face grades into the lower rim of the ectepicondylar foramen. The head of the humerus is comparable to that of the crocodile but has a much larger medial process. Dorsally the proximal region is gently rounded with the articular surface of the head set sharply above the surface of the bone. Both radial and ulnar condyles are well developed with the intercondylar fossa modified by an elevation of the ulnar articular surface.

In ventral view the broad intertrochanteric fossa and the popliteal region are apparent. The latter is modified by the anteroventral articular surface for the ulna. The

FIG. 3—*Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84a, ×0.4. *A*, *B*, lateral and mesial views of right pectoral girdle. *C*, Right manus.

small radial condyle is distorted in all specimens. This surface of the shaft is marked by rugosities proximally leading from the deltoid crest and doubtless marks the area of insertion of a portion of the adductor muscles. Both the preaxial and postaxial borders of this gently curving surface are clearly defined by muscle scars.

Radius.—The radius (fig. 7 C, D) is a long-shafted bone subcircular in section, with the dorsal surface rounded and the ventral surface concavely flat. The poorly ossified expanded proximal end is roundly oval. Distally the bone is more robust, with extensively developed rugosities for ligamentous attachments; a depression of the posterodorsal surface forms a surface for apposition with the ulna. A longitudinal ridge modifies the proximal third of the length posterodorsally. This bone is poorly preserved in both specimens.

Ulna.—The ulna (fig. 4 C, D) is massive proximally, the sigmoid notch forming a broad articular surface for the humerus. Incomplete ossification of the olecranon prevents an exact description, but it is evident that it extended dorsally, following the posterior curvature of the bone. The shaft is dorsoventrally compressed and heavier in front than behind. Dorsally the rounded surface is depressed in the central region of the proximal half of the shaft. A semilunate depression anterior to the sigmoid notch was probably related to the head of the radius, and a tuberosity is prominent on the central surface behind the depression. A longitudinal ridge is developed on the anterior half of the shaft. It extends onto the central surface of the distal end. Ventrally the shaft is shallowly excavated proximally and flattened centrally, a longitudinal ridge modifying the anterior third of the width.

The distal end of the ulna is poorly ossified and downwardly turned from the plane of the sigmoid notch of the proximal end. Anteroproximally the surface is roughly rounded; here muscle scars are continuous with a small ventroproximal tuberosity. The incurved posteroproximally expanded region is compressed and bears a small tuberosity midway between the narrowest portion of the shaft and the distal end of the bone.

PELVIC APPENDAGE

Remains of the pelvis (fig. 5A) are fragmentary. They include a left pubis, an almost complete left ischium to which is attached a portion of the right ischium, and all but the dorsal part of the ilium. Most of the left acetabular region was also recovered but is so distorted as to render it of little value. The ilium is described from a specimen found in the same quarry but only questionably associated with the skeleton.

Pubis.—The pubis resembles that of the phytosaur *Rhytidodon carolinensis* as described by McGregor (1906), but differs in having a small foramen in front. Laterally the surface is concave with a thin anterior and ventral margin, the latter incomplete. A small portion of the anteroventral section of the acetabulum is formed by the lateral half of the thick proximal surface of the bone. Dorsally the surface curves anteroventrally from the flat, thick, proximal surface. It becomes thinner and rounded peripherally where the greatest thickness is about 1 cm.

Mesially the pubis is convex, with a noticeably elevated central portion extending anteroventrally from the dorsal part of the proximal end to the region above the accessory pubic foramen, where the margin has its greatest thickness of 1 cm. The shape of the proximal end is shown in figure 5 where a dotted line follows the course of a ridge which divides the acetabular region of the pubis from that of the ilium.

Ischium.—The ischium is fused to the ilium at the acetabulum and meets its fellow at the midline. Dorsally it forms the posteroventral section of the acetabulum. Anteriorly, below a blunt unfinished surface, the preserved part of the bone tapers to a thin edge continuing to the point of junction with its fellow. The conjoined ischia extend outward about 30° from the perpendicular at the junction but gradually curve so that the terminal ends are very nearly horizontal. The apposed surfaces are concave dorsally as seen in section.

The mesial surface is gently convex in the central region and slopes gradually to the midline; the posterior end is produced, with the elements terminating in bluntly

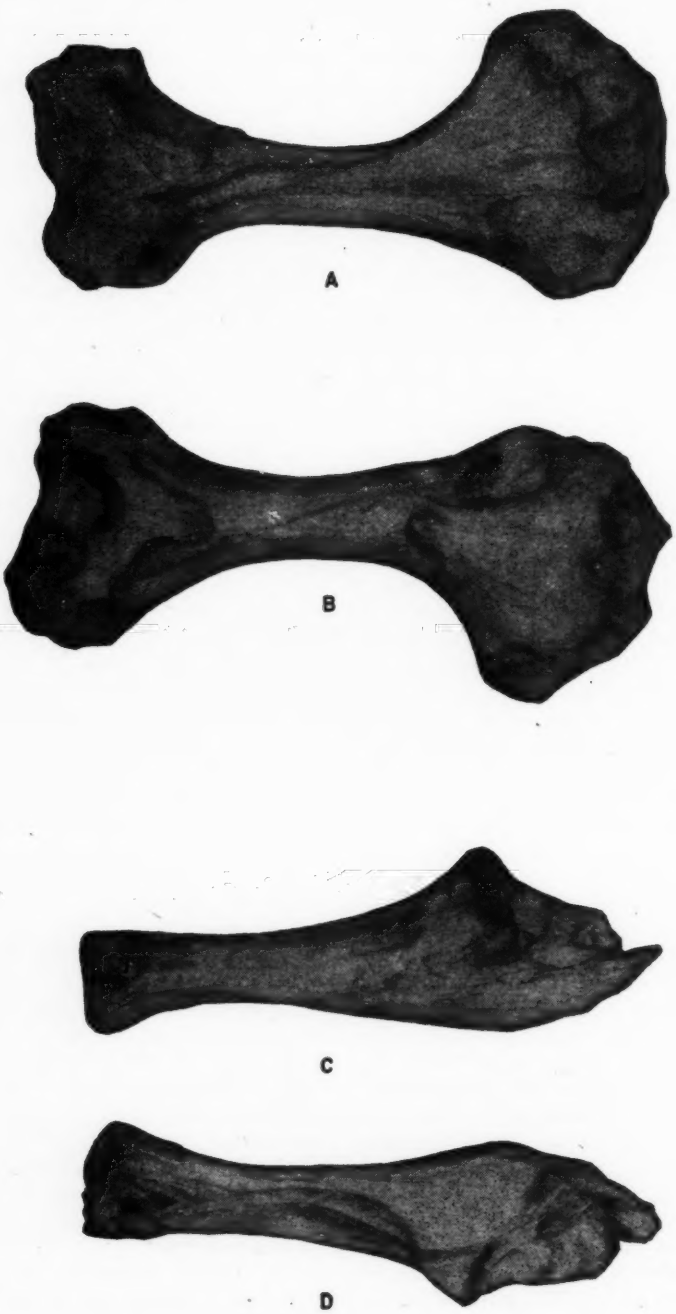


FIG. 4—*Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84a, ×0.4. *A*, *B*, Dorsal and ventral views of right humerus. *C*, *D*, Lateral and mesial views of right ulna.

rounded borders. Muscle scars are apparent posterolaterally.

Ilium (*specimen 31185-69*).—As seen laterally the ilium forms two-thirds of the fully concave acetabulum and is constricted dorsally at a broad neck, the well-developed posterior portion of the blade extending back to a bluntly tapered point. Anteriorly the blade ends abruptly with only a limited expansion from the neck. The upper surface is marked by muscle scars. Anterodorsally the acetabular rim is well defined with a prominent dorsal lip, merging posteriorly with a convex surface which defines the posterodorsal rim. Mesially the poorly preserved ventral region is convex, with rugosities curving down from the anterior region of the neck posteriorly and terminating beneath an excavated region above the neck. A sharply defined ridge limits the lower margin of the posterior two-thirds of the length of the blade. The latter is shallowly concave as seen in transverse section over the posterior three-fourths of its length; the anterior portion is nearly plane.

Femur.—The femur (fig. 7 A, B) is long-shafted and more expanded distally than proximally. As seen in posterior view the bone has a compound curvature, the head turning upward and forward and the distal end downward. Dorsally the intercondylar fossa extends as a shallow depression over the proximal third of the length. A pronounced sharp ridge occupying more than the central third of the shaft and bifurcating distally extends diagonally across the dorsal surface from the anterodistal face and merges with the posterior border of the head proximally. A strongly developed screw-shaped ridge modifies the posteroproximal surface, extending diagonally downward at less than 45° from its origin at the proximal third of the length of the bone. The posterior surfaces of the head and the lateral condyle are concave; the posterior face of the shaft anterior to the screw-shaped ridge is rounded. A small rugosity is apparent proximal to the ridge, and the posteriorly excavated region of the head is marked by tendon scars.

Ventrally the intertrochanteric fossa and the popliteal region are somewhat obscured by crushing. A well-developed ridge limits the intertrochanteric fossa posteriorly and curves anteriorly to approach closely the large fourth trochanter. The elevated adductor surface is a flat, slightly concave face, which slopes from the trochanter and tapers distally to the posterior condyle. It is delineated above and below by low ridges.

The anterior surface of the shaft is gently concave, faces anterodorsally on the proximal half of the bone, and curves to face anteroventrally on the distal half.

Tibia.—The tibia (fig. 6 A, B) is a short-shafted bone triangular in section with a broadly expanded head. Mesially the surface of the shaft is flat in the central portion and excavated beneath the head and at the distal end. Laterally the shaft is angularly rounded, the sharply elevated portion of the surface extending diagonally from the posterior region of the head to the central part of the distal end. An oval rugosity occupies the anterior angular border of the lateral face less than a third of the proximal length of the bone. The proximal end has two concave articular surfaces for the femur separated by an irregular central ridge, which is continuous with the cnemial crest. Posteriorly the head is rugose and excavated for the fibular articulation; rugosities at the periphery probably correspond to the capsular ligament of the femorotibial joint. The distal end is concave anteroposteriorly over the posterior two-thirds of its width and forms the articular surface for the tibiale. This surface is convexly rounded lateromesially.

Fibula.—No complete specimen is known; the descriptions are based on the distal three-fourths of the left (?) fibula of no. 31185-84a (fig. 6C) and the central portion of the shaft of a right (?) of no. 31185-84b (fig. 6D). The distinguishing feature of the bone is a large lateral double trochanter on the central portion of the shaft. This extends as a ridge from the posterocentral proximal portion of the shaft and becomes bifurcated into two prominent sharply ridged trochanters anteriorly. Above and mesial to this compound trochanter there is another poorly preserved elevated region which may be another trochanter. The lateral surface of the bone above and below the trochanters is rounded; the head was

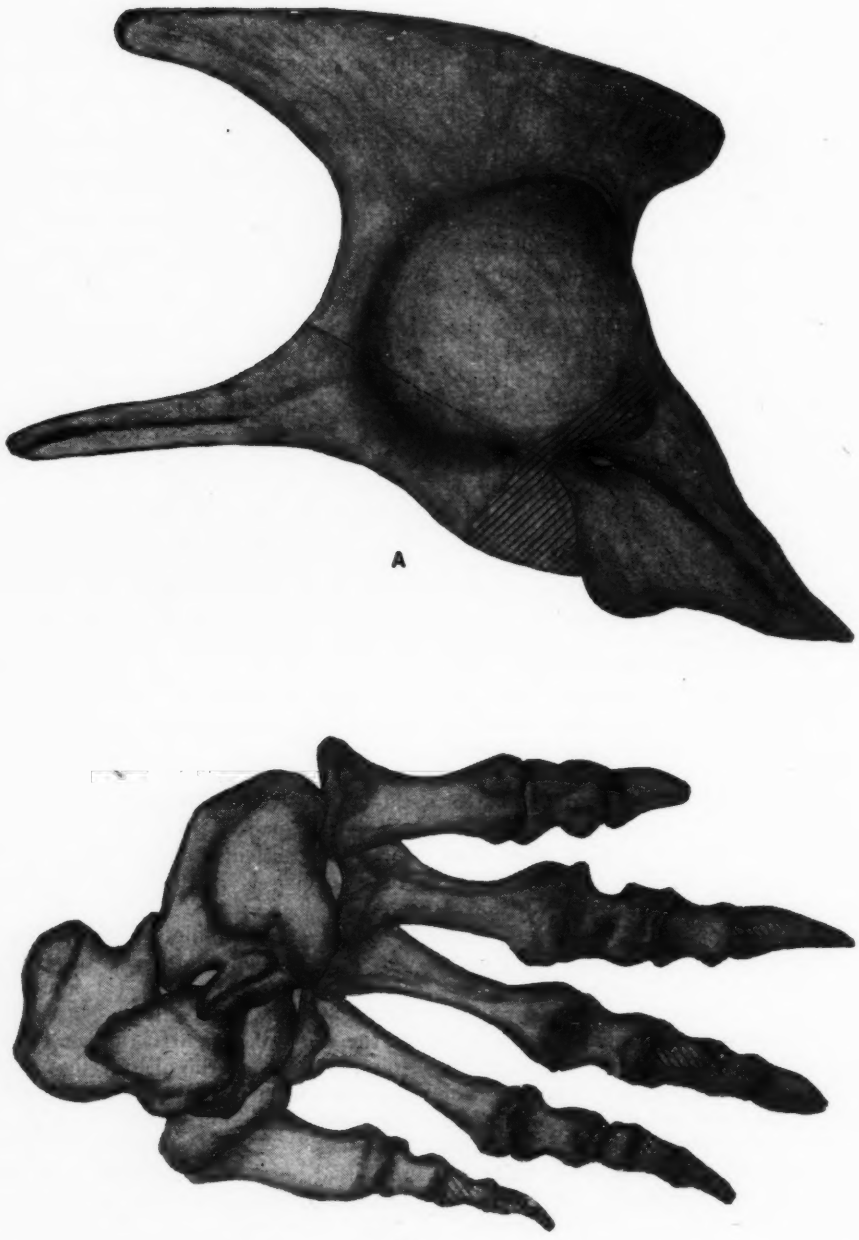


FIG. 5—*Typothorax meadei* Sawin, n. sp. *A*, Lateral view of right pelvis, ×0.4; ilium restored from Univ. of Texas no. 31185-69, ischium and pubis no. 31185-84a. *B*, Right pes, no. 31185-84a, ×0.4.

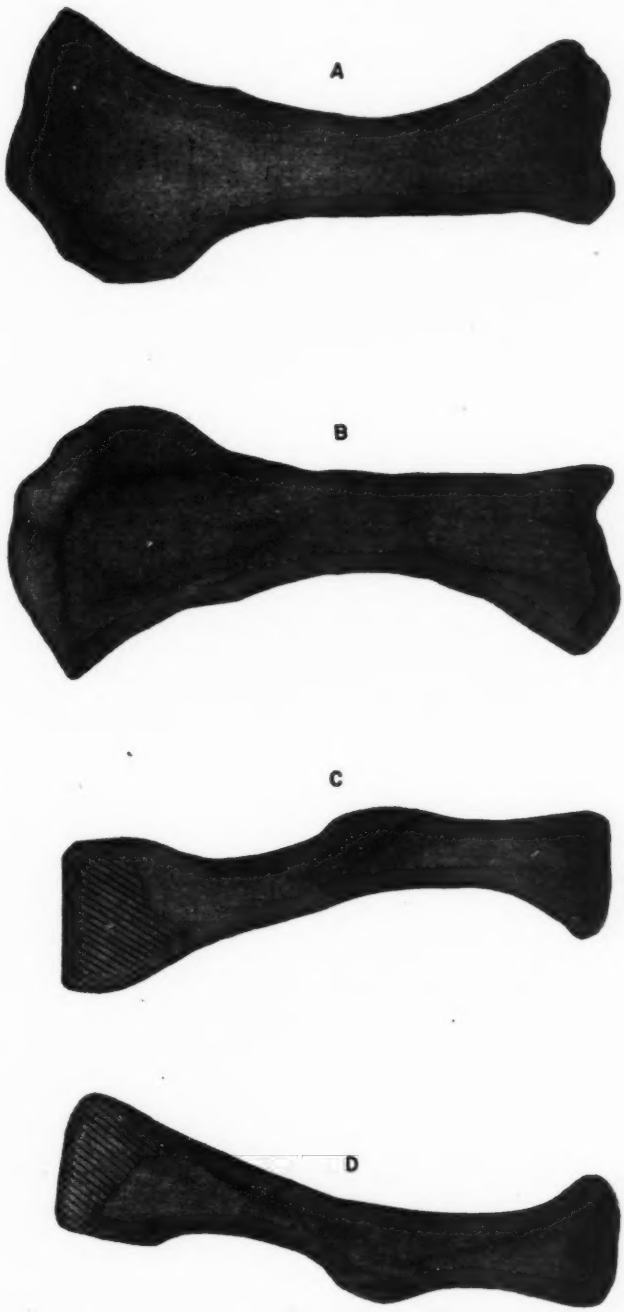


FIG. 6—*Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84b, ×0.4. *A*, *B*, Anterior and posterior views of right tibia. *C*, *D*, Lateral and mesial views of right (?) fibula.

evidently more flattened and expanded than the distal end. Mesially the surface slopes abruptly posterolaterally from a line which curves to the sharp posterior border from the central anteromesial portion of the shaft to the posterior distal end of the bone. Here it terminates as a small spur. Anterodistal to this line the bone is fully rounded. Above the trochanters the mesial surface is concavely flat, with a longitudinally elevated surface extending from the upper trochanter along the posteromesial border. The outline of the distal end is oval and slightly compressed on the mesial border.

MANUS

The phalangeal formula of the manus (fig. 3C) was probably 2-3-4-5-2. The digits are short and weakly developed. Some of the carpals are missing, and the poorly preserved elements show no similarity to the manus of the crocodile, as is the case with the pes. The major bone may represent a fused radiale and intermedium. Three other elements were found out of position but are doubtless distal carpals.

The proximal surface of the large proximal carpal is rounded over the portion that may have articulated with the radius; it is depressed mesially, where a contact with the ulna may have occurred. The lateral surface is irregularly rounded, and anteroventromesially a small oval facet 1 cm. in width faces ventromesially. Anteriorly the face is depressed centrally and expanded mesially, a small rounded protuberance modifying the upper and inner portion of the mesial face. Mesially the narrowest face of the bone curves abruptly down from the dorsal aspect to form a flat surface with an angular spur behind. This grades into the ventral surface with a gentle curvature in front. Dorsally the contours and surface are the shape of half a screw blade, with the lateral portion sloping gently from back to front and the mesial portion sloping more sharply from front to back. Ventrally the expanded lateral portion and the mesial area are elevated, with a depressed, slightly concave region at the constricted central area of the bone. Posteriorly the lateral expanded region slopes upward from an elevated region behind and beneath the oval articular surface.

The three other small elements are too badly worn for identification. One wedge-shaped bone has a well-developed articular surface conforming to the shape of the proximal ends of the metapodials and may represent one of the more lateral distal tarsals.

An irregularly rounded element may be associated with metacarpal *V* and a small rectangular element, ridged on the anterior (?) rim may have been the pisiform.

The metapodials are dorsoventrally compressed with expanded ends. Proximally the articular surfaces vary in form, but the distal surfaces are uniformly convexly rounded, with small conical pits lateroventrally for tendon insertions.

The first metacarpal is the stoutest and shortest, its proximal end curved sigmoidally on the ventrolateral face, which overlaps the dorsomesial portion of the proximal end of the second metacarpal. A similar overlap occurs on the four mesial metapodials. An outwardly curved, sharply elevated ridge on the dorsoproximal end of the second metacarpal borders a dorsal extension of the articular surface and forms a structural limit for the overlap. The third metacarpal is the longest of the series, exceeded only slightly in proximal breadth by the second. Its lateral border is upturned at the end of a longitudinal depression. Ventrolaterally the overlapping surface is convex; this feature is reflected in a deeper excavation of the dorsomesial proximal end of the fourth metacarpal. The latter does not have a prominent ridge to mark the end of the overlapping surface, and only a small ridge limits a groove for the extensor tendon. Metacarpal *V* is the most lightly built of the series, the distal end having less than two-thirds the width of the other elements.

Each phalanx has transversely concave proximal and convex distal articular surfaces with pits for tendon insertion as in the metapodials. A section of the central portion of the phalanx is rounded dorsally and flattened ventrally. Two clawlike unguals are preserved. The mesial surface is rounded; the lateral and ventral surfaces are flat, and the outline of the proximal end forms the quadrant of a circle.

PES

Tarsus.—Four elements make up the

tarsals (figs 5B, 10) These are more comparable to the crocodilian type than those of the aetosaurs or *Protosuchus* and from the functional aspect were probably similar to the alligator (cf. Schaeffer, 1941, fig. 16, p. 443). Both the tibiale and fibulare are massive and differ most conspicuously from those of the alligator in the more limited mesial articular surfaces, those of the fibulare forming an angular recess in the mesiocentral portion of the bone. The pyramidal lateral tarsal contacts the fibulare at a flat surface and provides articular facets for metatarsals *V* and *IV*. A small luniform mesial tarsal appears to articulate with metatarsal *III*.

The fibulare has a large, oval, convexly rounded articular surface shared equally by the tibiale and the fibula. Anteromesially a semicircular concavity provides an articular surface for the ventral hooked process of the tibiale. The anterior face of the body of the bone has a plane surface sloping downward and backward to accommodate the lateral distal tarsal. The heel is convex above and concave below, with a groove from the posterolateral region of the bone interrupting the rounded margin of the concavity. The heel is expanded and convex behind with a reniform outline.

The tibiale of the right pes was found in articulation with the tibia. Its surface is depressed centrally; it slopes upward to the border in front, and downward and laterally behind. Posteriorly the bone is rounded mesially from the flat mesial surface. This is produced into a hooklike, bluntly rounded process, which curves ventroanterolaterally to articulate with the anteromesial recess of the fibulare. A concavity modifies the lateral half of the posterior surface, the inward curvature being more pronounced for the upper margin than the acute lateral margin. Ventrally the mesial two-thirds of the surface is rounded, with a slight depression centromesially. The surface of articulation with the mesial portion of the rounded fibular articulation of the fibulare slopes dorsomesially from the hooked process to curve laterally. This flattened surface overlies the mesial half of the rounded articular surface of the fibulare, the lateral half forming the articular surface for the fibula. Laterally the tibiale has an irregular square face depressed centrally, the axis of the depression extending from the lower front corner to the upper back corner. Anteriorly the body of the bone curves abruptly from the mesial and dorsal face to form articular surfaces for metacarpals *I–III*. Dorsolaterally the bone curves abruptly posteriorly, forming a pulleylike groove between the body and the inset convexly faced portion overlying the fibulare.

Distal tarsals.—The pyramidal lateral element presents a triangular posteromesially oriented flat face to the fibulare and forms an articular surface for metatarsal *V* laterally. Dorsolaterally the bone is wedge-shaped and roughly convex, this portion being visible when the foot is in articulation. Anteriorly this element is roundly triangular in outline and slightly concave. Ventrally the poorly preserved surface is rounded.

The mesial distal tarsal is spur-shaped with a flattened anterior face probably articulating with the third and fourth metatarsals.

Metatarsus.—Elements *I–IV* overlap proximally as shown in figure 5B, the first two metapodials having a loose articulation with the tibiale. Their form is essentially crocodilian with the exception of metatarsal *V* which is fully developed with an articular surface for the phalanx.

Phalanges.—The phalangeal formula is 2-3-4-5?-3. Claw-shaped ungual elements are very stoutly developed on the first and second digits but are smaller on the lateral members. A typical phalanx is rounded dorsally, concavely flattened ventrally with the proximal expansion larger than the distal. Proximally the articular surface is concave and triangular in outline, sloping proximally from the dorsal surface at an angle of about 45°. Distally the articular surface is pulley-shaped, and small cone-shaped excavations for digital tendons occupy the lower lateral portions of the bone.

ARMOR

The dorsal armor (figs. 8, 11, 12) is arranged in bands of four plates consisting of two centrals and two lateral spine-bearing elements corresponding with each vertebra from the shoulder to the proximal caudal region. Anteriorly the plates are longer than the vertebrae; the first seven, if correctly

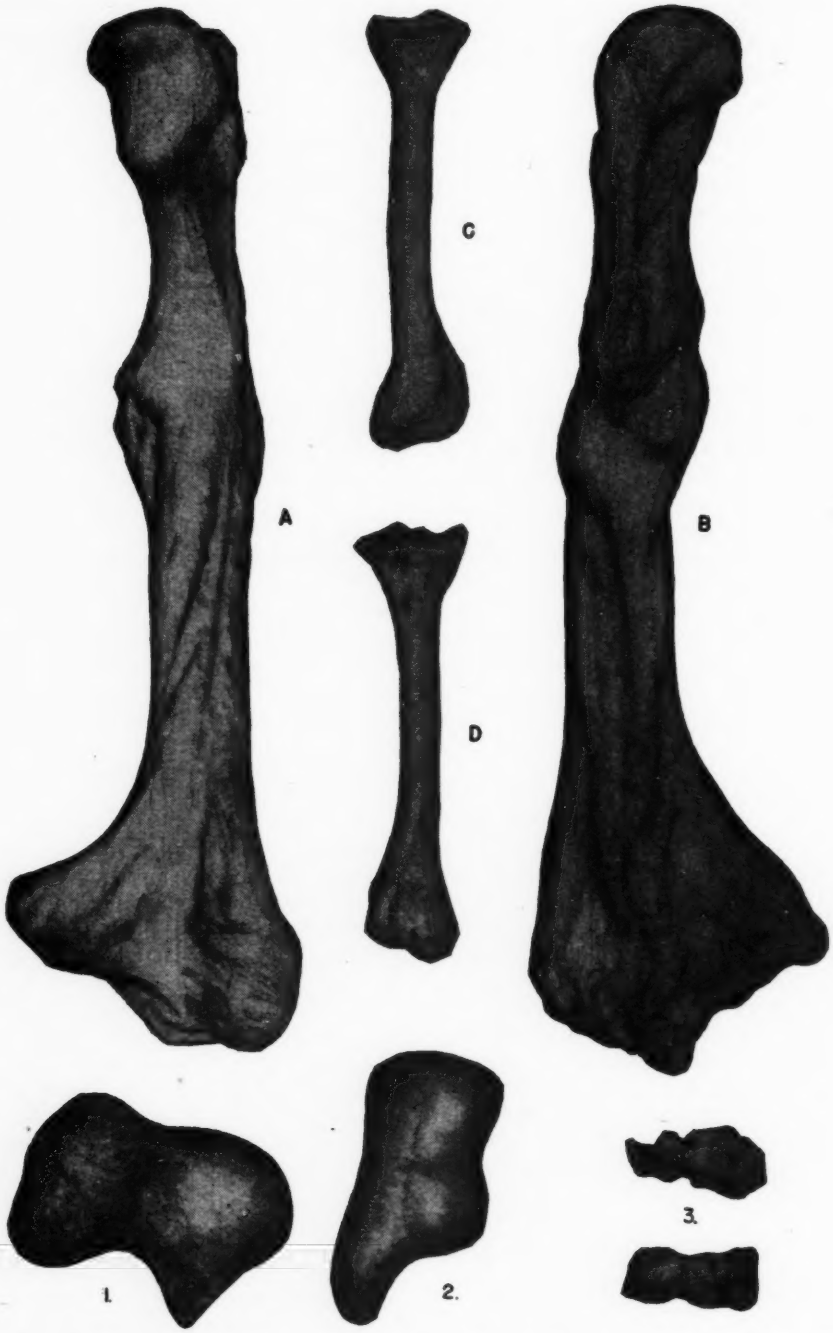


FIG. 7—*Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84a, ×0.4. *A*, *B*, Anterodorsal and posteroventral views of left femur. *C*, *D*, Lateral and mesial views of right radius. *1*, *2*, Distal and proximal ends of femur. *3*, Anterior and ventral views of "radiale."

restored, apparently overlie the entire cervical series. It is possible that several bands in the proximal caudal region had median plates instead of two central elements to form a transition to the tail, where only the spine-bearing plates form the dorsal armor. The distal three-fourths of the caudal region differs from the anterior plates in having paired lateral and ventral elements, which probably completely enclosed the tail from a point behind the cloaca to the distal end. Thin quadrilateral scutes probably protected the abdomen and the more mobile integument of the body was covered by buttonlike scutes or imbricating curved scales, several of which were removed from the limb bones in the course of preparation.

Dorsal series.—The first spines, known in part from no. 31185-84b, are oriented posterodorsolaterally; the sixth to tenth become progressively more laterally placed with the thirteenth to nineteenth having a slight upward slope to the top and backwardly curved anterior borders. From the twentieth to the twenty-fifth there is a very slight upward slope and little or no backward curvature. Caudally the spines become progressively smaller and dorsoposteriorly oriented. The largest spines, seventh and eighth of the series, are in the shoulder region and correspond to the greatly developed horn of *Episcoposaurus* (*Desmatosuchus*) in position. *Typothorax* differs from *Episcoposaurus* in the development and orientation of the spines, considerable variation occurring in the latter in the nuchal series and in the placement of the body plates, which are dorsally instead of laterally oriented.

The first nuchal band of plates (fig. 8A1, B1) were doubtless articulated with the skull, the spine-bearing elements adhering to the occipital region in specimen no. 31184–85b. Centrally the median pair of plates probably overlapped the skull to a point beyond the dorsal ridge of the occiput. The spine-bearing plate is incomplete laterally; the spine is produced posterodorsolaterally and has a length of 7.5 cm. as measured along the anterior border. There is a sharp dorsal ridge and the posteroventral surface is concave. The anterior margin of the plate is indented to conform to the shape of the posterior border of the upper temporal opening of the skull. The articular surface for the mesial plate has an angular abutment adapted to the upward curvature of the lateral.

The mesial plate is longer anteroposteriorly than laterally, with the finished anterior border less than two-thirds the breadth of the posterior. Dorsally the surface is convex, sculptured with shallow pits anteriorly, and modified by a small rounded posteromesially directed eminence on the mesial third of the posterior border. The ventral surface is gently concave from side to side anteriorly, the concavity becoming pronounced posteriorly beneath the base of the eminence. The longitudinal curvature is sigmoidal, the thin anterior lip turning gently upward and the thick posterior articular surface for the second plate turning downward.

The succeeding four spines and plates are incompletely known from the principal specimen, a left spine for the second and fifth segment and a plate on the right side for the fourth segment being embodied in the restoration. Some of the missing elements of this region are partly known from fragments in specimen no 31185-84b, however, and an excellently preserved isolated spine (31098-29) permits a fairly complete reconstruction of the midcervical series.

The typical angular spine-bearing plate has a well-developed articular collar over a quarter of the length of the plate, forming a surface for overlap for the preceding segment. The dorsal portion of the plate slopes upward toward the articular surface with the median element and forms an angle of 80° with the lobe-shaped lateral region. Only the upper third of the lateral portion forms an articular surface, the margin of the plate extending as a free-edged, tongue-shaped surface beneath the base of the spine. The dorsal surface of the spine is convex, with a ridge, slightly developed in the anterior members of the series, extending longitudinally from the posterocentral portion of the plate. This surface of the spine forms an acute angle with the deeply convex anteroventral face. Posteriorly the spine is rounded for the distal two-thirds of its length and is incurved at the base, which bifurcates to merge with the posterior borders of the top and sides of the plate. The

inner surface is smooth. It curves evenly from the dorsal to the lateral surface anteriorly but grades into a sharper curvature posteriorly, where the region beneath the spine is deeply and angularly concave. Here it slopes outward and slightly upward, merging with the incurved region at the base of the posterior portion of the spine. The dorsal portion of the plate is twice as thick as the lateral portion. Irregularly placed pits form the sculpture at the mesial surface of the dorsal region and anteriorly and laterally at the base of the spine.

The median plates referable to this series are not well known. Fragments show that they were more strongly curved upward to the midline than the posterior median elements, and that the region of overlap was greater to permit motion in the neck. Sutural borders with the lateral plates are straight rather than sigmoidal, and in the more posterior members of the series the articulation, although visible, is fused with the sutural border to extend outward from front to back, where the body becomes expanded at the shoulder region. The pyramidal bosses are relatively closer to the midline than those farther back, and the plates near the pectoral girdle slope upward from front to back as seen in sagittal section.

7th and 8th series.—The anteroventral face of the seventh spine (figs. 8A2, B2) is flat, with a very low longitudinal ridge modifying the lower central surface. It forms an abrupt angle of 90° with the dorsal surface. This face has a broad well-developed central longitudinal ridge, which becomes lower toward the tip of the spine. The anterior border of the convex ventral surface is ridged, this face forming an angle of about 115° with the anteroventral face. The spine is concavely excavated behind. The ventral face merges with the lateral region of the spine-bearing plate, and the dorsal face extends to the horizontally oriented dorsal part of the plate. The latter continues to the median plate, which it joins at a sigmoidal articular border. The sharp anterior articular surface of the spine-bearing plate is smooth for a distance of 2 cm. from the edge to provide a surface of overlap for the preceding plate. Posterior to the articular surface the dorsal portion of the plate mesial to the base of the spine is depressed. The plate becomes elevated centrally and posteriorly to conform to the contours of the base of the spine. Small pits form the sculpture.

The smooth ventral surface is sigmoidally curved as seen in longitudinal section, the anterior portion curving ventrally to the convex central region. Here the bone recurves to form a dorsally concave surface behind.

The lateral surface beneath the base of the spine has a margin of finished bone curving down from the anterior articular border to the lowermost region beneath the posterior border of the spine. This margin is slightly indented below the ridge at the anterior edge of the ventral face of the spine.

Median plate.—The median plate is convex from side to side and slopes upward to the median line and the articular surface with the opposing plate. A three-sided pyramidal boss occupies the mesial third of the posterior border. Small pits 2 to 3 mm. in diameter form the sculpture of the dorsal surface. The under surface has a sigmoidal curvature as seen in longitudinal section, conforming to the contours of the spine-bearing plate; the region beneath the eminence is almost hemispherically concave.

Eighth segment.—The eighth segment is similar to the seventh, the median plate sloping upward from front to back to complete the curvature from the neck to the shoulder. There is also a pronounced curvature of the plate from the lateral border to the midline. This segment and the succeeding band form a transition from the cervical series to the body series, the spines becoming more horizontal in position and the median plates grading into a more gentle curvature as seen in transverse section.

Spine bearing plates of the ninth to eighteenth segments.—The spines are oriented dorsolaterally and project posteriorly. The anteroventral face is roundly convex, with a slight longitudinal ridge on the upper third of the face. The dorsal face is more gently convex, joining the lower face to form the angular anterior edge of the spine. At the base the posterior portion is excavated along the proximal third to half of the spine's length, the V-shaped indentation becoming broader at the base and merging with the

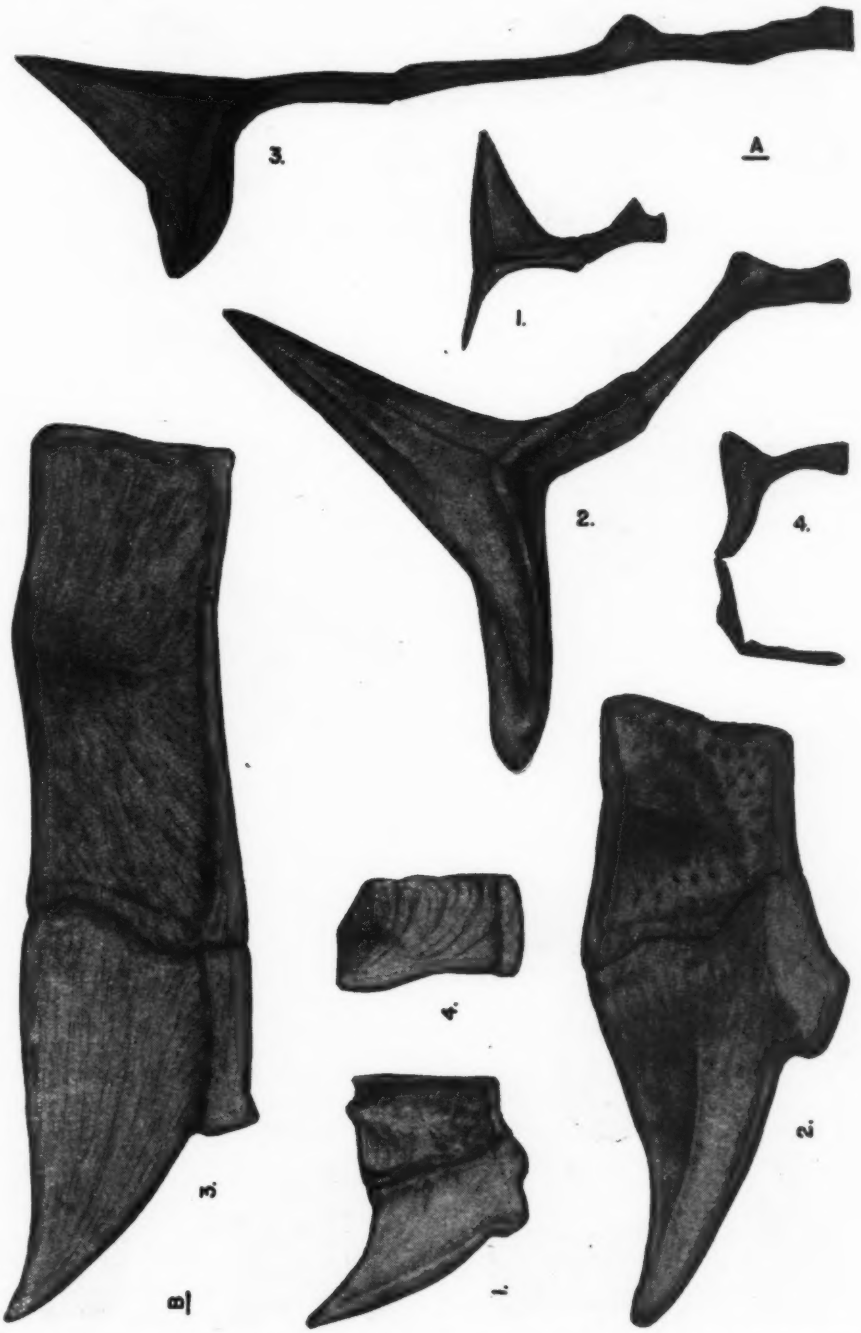


FIG. 8—*Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84a, ×0.4. *A*, *1–4*, Anterior views of right halves of armor segments; *1*, first nuchal plate; *2*, seventh nuchal plate; *3*, thirteenth (midbody) plate; *4*, thirty-eighth (caudal) plate. *B*, *1–4*, Dorsal views of right halves of armor segments; *1*, first nuchal plate; *2*, seventh nuchal plate; *3*, thirteenth (midbody) plate; *4*, thirty-eighth (caudal) plate.

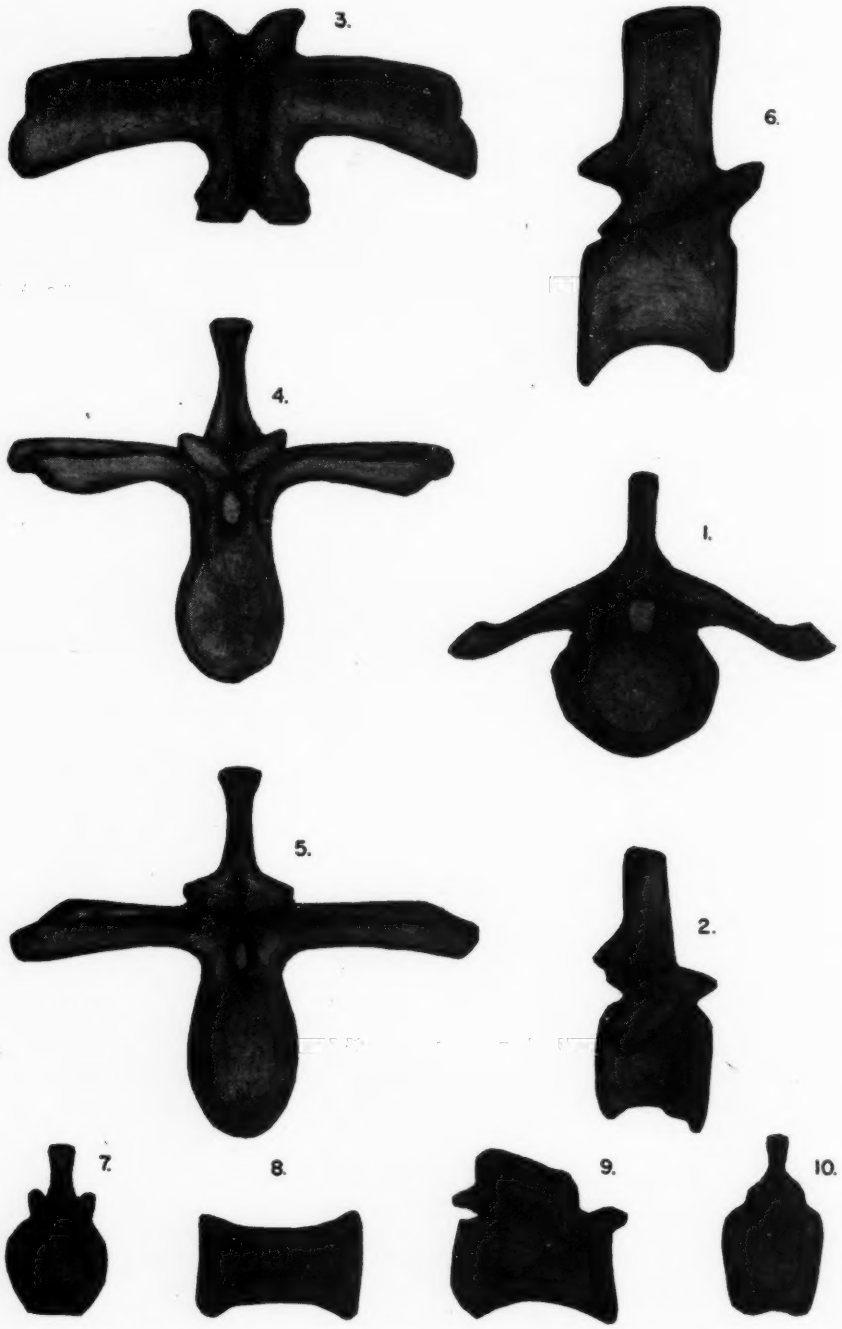


FIG. 9—*Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84a; 31098-29; 31185-84b, ×0.4. Ninth cervical vertebra (composite); *1*, anterior view, *2*, lateral view. Midthoracic vertebra; *3*, dorsal view, *4*, anterior view, *5*, posterior view, *6*, lateral view. Midcaudal vertebra; *7*, anterior view, *8*, ventral view, *9*, lateral view, *10*, posterior view.

mesial angle formed by the dorsal and lateral portions of the plate. Dorsally the plate curves slightly downward from the sigmoidal articular border with the median plate, its gentle convexity becoming more pronounced at the upward curvature at the base of the spine. The anterior one-fourth to one-fifth of the length of the plate forms the articular collar for the preceding plate. As seen in sagittal section this collar is convex dorsally, a transverse groove marking its posterior border. The ventral outline of the best-preserved plates is sigmoidal as seen in section, the anterior border curving slightly upward and the posterior border downward. Laterally the plate slopes upward to conform to the contours of the base of the spine. The ventral border slopes posteroventrally and has a slight indentation at the posterior end of the articular surface. The remainder of this border shows no definite articular surface for abdominal scutes; these probably were separated by a small interval occupied by connective tissue. Sculpture of shallow pits is present on the dorsal surface, and pits and ridges are more definitely developed on the lateral face. The spine is devoid of sculpture.

The dorsal and the lateral surfaces of the spine-bearing plates form an angle of about 100° as measured anteriorly. The ventral surfaces are curved at the angle beneath the anterior portion of the spine. Beneath the base of the spine there is a concavity which merges with the V-shaped excavation at the posterior. In some plates there is an inset region of bone corresponding to the articular collar of the succeeding plate, but the preservation suggests that this might be due to crushing.

In general the spine-bearing plates of the body region have longer spines (11.2 cm.) and longer plates anteriorly. Posteriorly the plates become wider but the spines diminish in size to the midbody region and there maintain a fairly constant length of 9.0 cm. through the pelvic region. The median plates are widest just behind the midbody region.

Median plates of the ninth to eighteenth segments.—Typical plates of this series are quadrilateral, with the lateral dimension one-third the transverse. They join the spine-bearing plates laterally at a sigmoidal articular border and slope upward to meet at the middorsal line. The dorsal surface is modified by pits 0.5 cm. in diameter, which radiate from an unsculptured three-sided pyramidal prominence situated on the posteromesial third of the border of the plate. Anteriorly the sculptured surface slopes upward to a smooth, thin-lipped, articular area overlapped by the preceding plate. Ventrally the plate is smooth, shallowly sigmoidal in outline as seen in longitudinal section, and gently arched beneath the pyramidal prominence. In transverse section it has an upward curvature to the midline.

Pelvic series (19–24).—Spine-bearing plates of the pelvic region have a broader dorsal surface mesial to the base of the almost horizontal spine, the latter extending but slightly posterior to a line across the posterior margin of the median plates. The angle between the lateral and dorsal faces is less than in the anterior plates, measuring 70° in the middle of the series. On the upper surface the spine is flatly convex, with the greatest elevation occurring on a longitudinal line at the anterior third of the dorsal face. Anteroventrally the face is convex and flattened posteroproximally. The spines diminish in size caudally. Only two of the median plates are preserved. They differ from the preceding elements in having a greater length but lesser width. The transition to the true caudals is unknown except for one spine-bearing plate arbitrarily interpolated in the restoration.

Mid-caudal segment.—Only fragmentary remains of the caudal plates (fig. 8A4, B4) are known in specimen no. 31185-84a but no. 31100-425, representing two-thirds of a tail, is relatively complete. Several segments of the latter were articulated, showing the complete caudal armor, which probably extended forward nearly to the cloacal region. Paired angular spine-bearing plates cover the dorsal and dorsolateral region of the tail. The low spine is posterodorsolaterally placed, ornamentation of low ridges converging at the spine base from the dorsal and lateral faces of the plate. A sigmoidal curvature of the dorsal plate as seen longitudinally is similar to that noted for the anterior elements. Ventrolaterally the surface is covered by thin quadrilateral, vertically placed plates twice as long as wide.

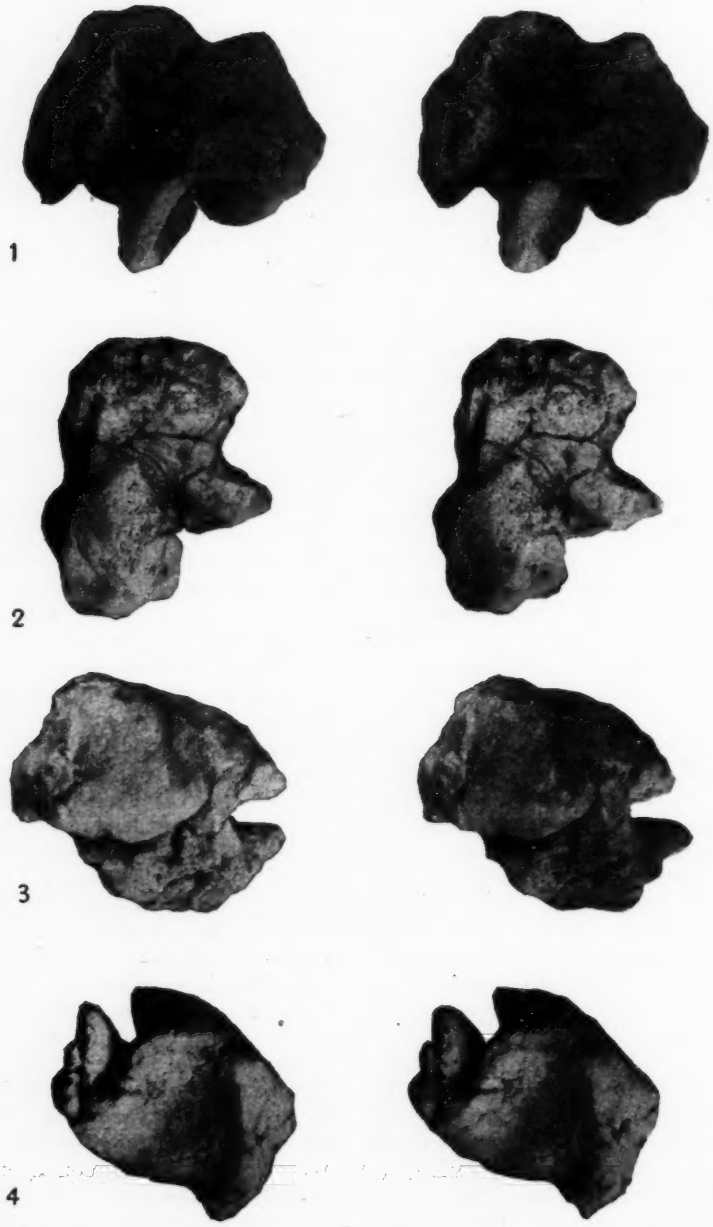


FIG. *10—Typothorax meadei* Sawin, n. sp. Univ. of Texas no. 31185-84a. Stereo pairs, ×0.4. *1*, *2*, Dorsal and ventral views of right tibiale. *3*, *4*, Dorsal and ventral views of right fibulare.

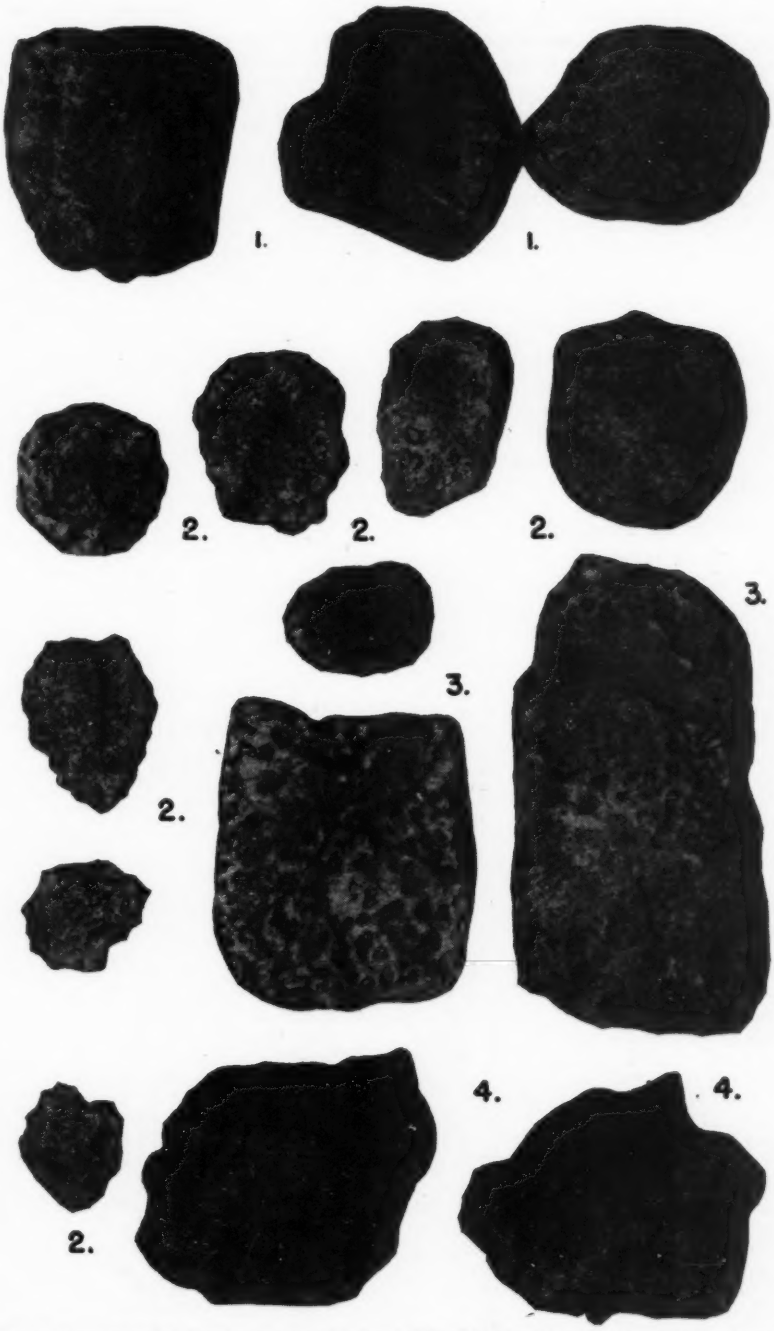


FIG. *11—Typothorax meadei* Sawin, n. sp. Abdominal and miscellaneous armor. *1*, Lower neck or shoulder scales; *2;* appendicular scales; *3*, abdominal scales; *4, Promystriosuchus*? armor.

The lower surface forms a straight articulation with the ventral plate, but dorsally the border is gently curved, with no definite articular surfaces, this portion of the plate probably separating from the ventral portion of the dorsal plate with the expansion of caudal muscles. An oval keel on the central surface arises at the anterior fourth of the length and terminates sharply close to the posterior border. Irregular small pits form the sculpture.

The ventral plates are also quadrilateral, slightly wider in front than behind and modified ventrally by weakly developed pits and ridges radiating from the anterocentral center of ossification. They join mesially at a straight articulation and at a similar articular junction meet the ventrolateral plates laterally.

ENDOSKELETAL MEASUREMENTS

Skull 31185–84b

Skull roof

Length (estimated)	19.50 cm.
Length of external naris (estimated)	5.20 cm.
Width of external naris	2.00 cm.
Length of right anteorbital fenestra	7.7 cm.
Width of right anteorbital fenestra	2.46 cm.
Length of left anteorbital fenestra	4.52 cm.
Width of left anteorbital fenestra (crushed)	2.10 cm.
Width between temporal fenestrae	7.7 cm.
Width interorbital	6.8 cm.
Width at posterior rims of nares	4.3 cm.

Occiput

Height from base of occipital condyle to skull roof	7.85 cm.
Width at quadratojugals (estimated)	12.6 cm.
Number of maxillary teeth	11–13
Number of premaxillary teeth	6+

Jaw

Total length	22.7 cm.
Height at coronoid	5.8 cm.
Length of mandibular vacuity	6.1 cm.
Height of mandibular vacuity	2.65 cm.
Number of teeth	7

Scapulocoracoid 31185–84a

Greatest height (estimated)	28.5 cm.
Distance anterior of glenoid to top of scapula	21.6 cm.
Height of glenoid	4.2 cm.
Depth of dorsal face of glenoid	3.4 cm.
Depth of ventral face of glenoid	2.9 cm.
Thickness anterior to glenoid	4.1 cm.
Width of neck (estimated)	3.7 cm.

Pelvis 31185–69; 31185–84a

Ilium

Length (estimated)	20.5 cm.
Width of neck	9.2 cm.
Width at base	12.9 cm.

Ischium

Length	13.14 cm.
Width at midlength	3.3 cm.

Left pubis

Length	12.2 cm.
Width	?

Limb Bones

Measurements in centimeters	Length	Proximal width	Distal width	Greatest thickness of shaft
Right humerus 31185-84a	21.00	9.82	9.85	2.87
Left humerus 31185-84a	20.50 est.	Distorted		
Right humerus 31185-84b	21.00 est.	9.90		2.90
Right radius 31185-84a	14. est.	3.8 est.	3.4 est.	
Left radius 31185-84a	14.3	3.6 est.	3.3 est.	1.45
Right ulna 31185-84a	19.12	7.0 est.	3.65	2.7
Left ulna 31185-84a	17.9	6.7	3.70	2.7
Right femur 31185-84a	33.9	8.0	10.0 est.	4.3
Left femur 31185-84a	33.4	8.51	9.2 est.	4.18
Right femur 31185-84b	30.8 est.	9.0 est.	9.5 est.	4.13
Left femur 31185-84b	32.8	8.66	9.37	3.9
Right tibia 31185-84a	19.5	6.12	8.76	3.4 est.
Left tibia 31185-84a	19.2	5.96	8.0 est.	3.3 est.
Right tibia 31185-84b	19.07	5.18	8.28	3.3
Left tibia 31185-84b	19.2	5.44	8.2	2.98
Left? fibula 31185-84b	17.5 est.	4.33	3.8 est.	2.9

Right Manus 31185-84a

Length of "radiale"	5.02 cm.
Greatest width of "radiale"	2.1 cm.

Posteriorly the ventral caudal plates become single and the posterior border is indented at the midline. The spines become lower, shorter, and more dorsally placed. The dorsal and lateral surfaces become rounded, and there is apparently a greater surface of overlap toward the distal end.

Abdominal and appendicular armor.—Four thin plates (0.3–0.5 cm.) and many fragments were found in association with

	Metacarpals	Phalanges				
		1	2	3	4	5
		Length (cm.)				
Digit 1	3.15	1.7	2.7	—	—	—
Digit 2	3.90	2.17	1.42	×	—	—
Digit 3	4.23	1.78	×	×	×	—
Digit 4	3.74	1.42	1.02	0.70	0.50	×
Digit 5	3.33	1.3	×	×	×	—
		Proximal width (cm.)				
Digit 1	2.54	1.75	1.15	—	—	—
Digit 2	2.60	2.05	1.43	×	—	—
Digit 3	2.50	1.77	×	×	×	—
Digit 4	2.33	1.67	1.10	0.75	0.60	×
Digit 5	2.42	1.21	×	×	×	—
		Distal width (cm.)				
Digit 1	1.97	1.51	—	—	—	—
Digit 2	1.98	1.60	1.36	×	—	—
Digit 3	1.98	1.30 est.	×	×	×	—
Digit 4	2.00	1.19	0.87	0.58	×	×
Digit 5	1.38	0.98	×	×	×	—

Right Pes

Calcaneum: Length 8.32 cm.; width 7.15 cm.; width of facet for lateral tarsal 4.94.
Astragalus: Length 7.51; width 6.06.
Lateral proximal tarsal: Width 5.3 cm.; thickness 3.4 cm. est.
Mesial proximal tarsal: Width 3.45 cm.; thickness 1.43 cm.

	Metatarsals	Phalanges				
		1	2	3	4	5
		Length (cm.)				
Digit 1	6.86	2.7 est.	4.3 est.	—	—	—
Digit 2	8.34	3.35	L 2.53[1]	L 3.8	—	—
Digit 3	9.58	2.85	L 2.10	L 1.80	×	—
Digit 4	8.03	2.5	1.60	×	×	×
Digit 5	6.6 est.	2.2	—	—	—	—
		Proximal width (cm.)				
Digit 1	3.5 est.	3.98	1.82	—	—	—
Digit 2	3.95	3.0	L 2.31	L 1.76	—	—
Digit 3	3.70	2.61	L 2.24	L 1.73	—	—
Digit 4	3.04	2.60	1.82	×	×	×
Digit 5	4.88	2.10	—	—	—	—
		Distal width (cm.)				
Digit 1	2.94	2.19	×	—	—	—
Digit 2	2.92	2.48	L 2.0	—	—	—
Digit 3	2.58	2.41	L 2.03	—	—	—
Digit 4	2.67	2.10	1.43	×	×	×
Digit 5	2.3 est.	1.5	—	—	—	—

[1] L signifies left.

Vertebrae				
	Dimensions of centrum			
	Ventral length	Posterior width	Posterior height	Width at midlength of ventral third
1.	1.95	2.90	2.30 est.	2.72
2.	3.81	2.93	3.02	1.98
3.	2.91	3.25	3.0	2.36
4.	2.92	3.55	3.2	2.28
5.	2.80	3.42	3.05	2.31
6.	2.90	3.72	3.30	3.56
7.	3.10	3.68	3.49	2.30
8.	3.23	3.62	3.60	2.18
9.	3.35	3.74	3.53	2.39
10.	4.18	3.60 est.	3.28	2.30 est.
11-13 missing				
14.	4.24	3.03	3.70	1.75
15.	4.55	3.20	3.60 est.	1.60
16-19 distorted or missing				
20.	4.85 est.	3.9	4.63	1.70
21.	4.98	3.96	4.8 est.	
22.		3.80 est.	4.55	
23-25 missing				
26.	5.8 est.	4.1 est.	5.4 est.	
27.	5.6	4.6	5.58	1.95
28.	5.55	4.5 est.	5.2 est.	2.02
29.	5.68	4.3	4.63	1.90
30.	5.55	3.9		1.85
31.	missing			
32.	5.65			
33.	5.92	3.6	3.4	
34.	5.53	3.45	3.3	
35.	5.55	3.3	3.15	1.9
36.	5.42	3.58	2.98	1.8
37.	5.45	3.4	2.75	2.0
38.	missing			
39.	5.2	3.0		1.81
40.	5.31	2.76	2.81	1.72
41.	4.80	2.50 est.	2.64	1.52
42.	4.85			1.60 est.
43.	4.9			
44.	4.45			1.4 est.
45.	4.25			
46.	3.82	2.30 est.	1.80 est.	1.50 est.
47.	3.44			1.31
48.	missing			
49.	3.2 est.			1.1
50.	2.8 est.	1.6	1.2	0.91
51.	2.62	1.6 est.	1.18	0.80

specimen no. 31185-84a representing remains of the abdominal armor. These are irregularly quadrilateral, slightly concave longitudinally on the inner side, and range from straight to slightly convex transversely. A sculpture of irregularly shaped pits rarely over 0.4 cm. in size radiates from the central portion of the plates (fig. 11). There is no evidence of articular surfaces on any of the borders, and it may be inferred that these plates were probably embedded in the dermal layer and joined by connective tissue.

The appendages were probably covered by imbricated "scales" or buttonlike elements, several of which were found adherent on limb bones. The scales are ovate, the larger elements bearing a central or sub-

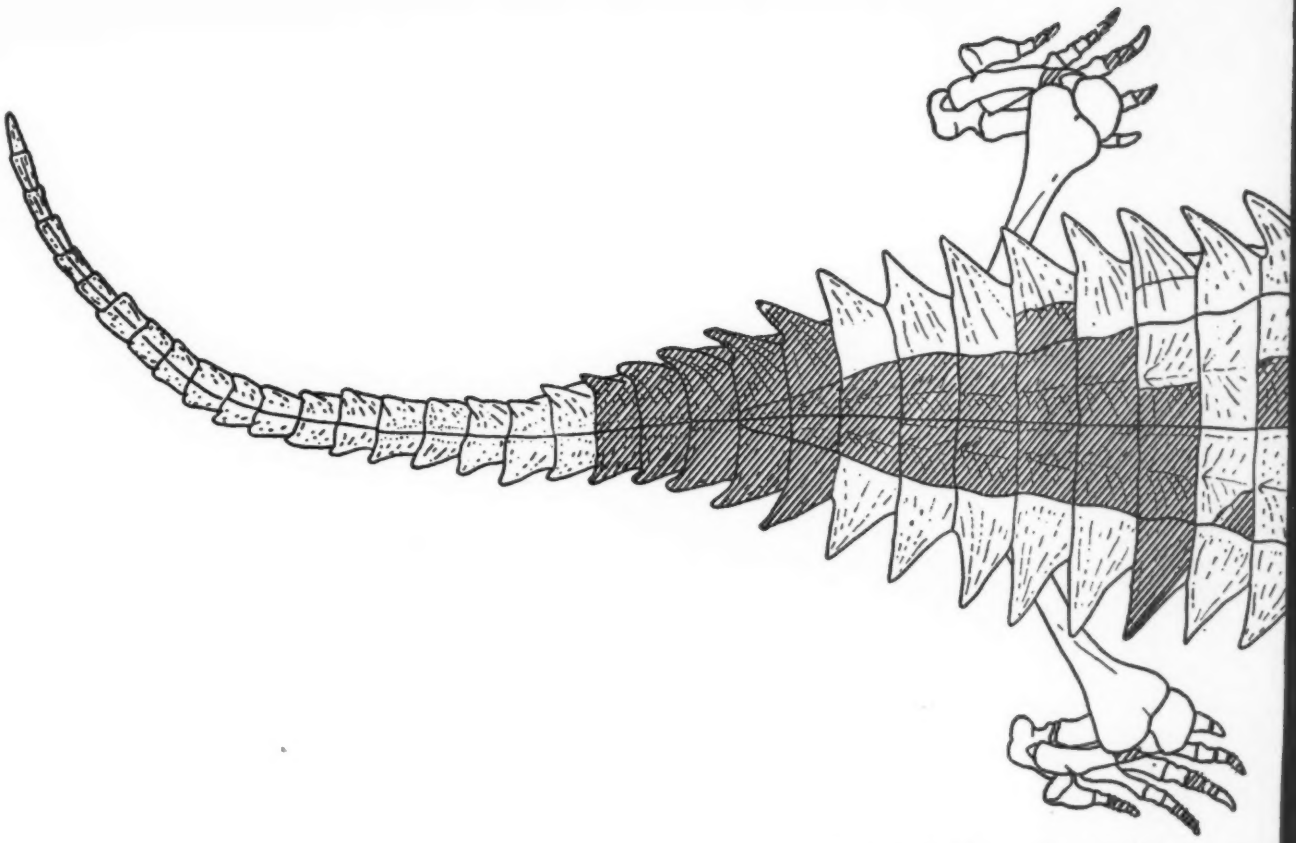


FIG. *12*—*Typothorax meadei* Sawin, n. sp. Resto

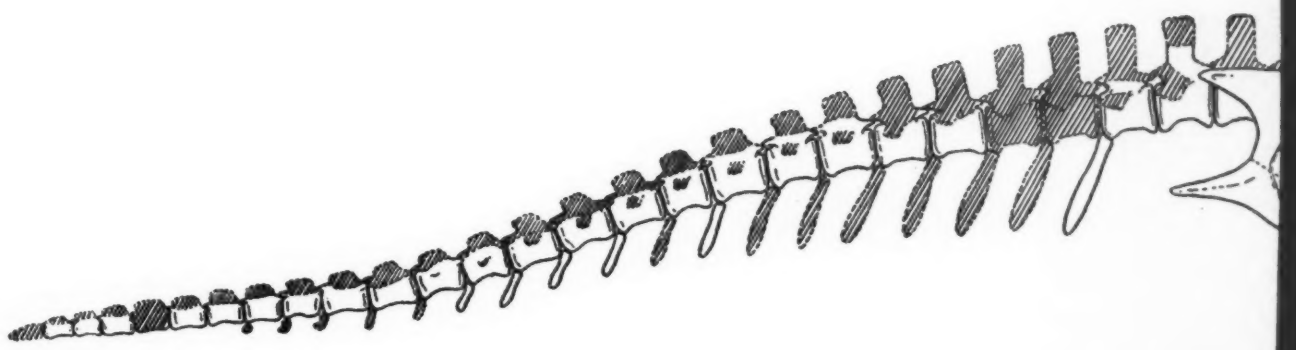
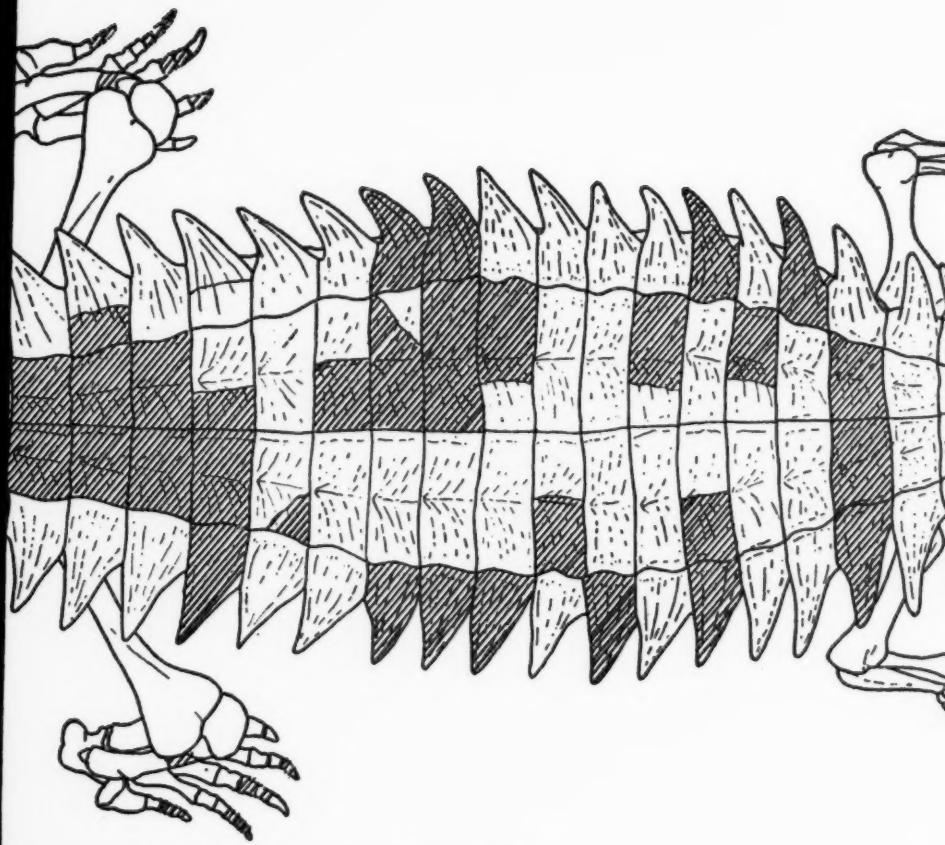
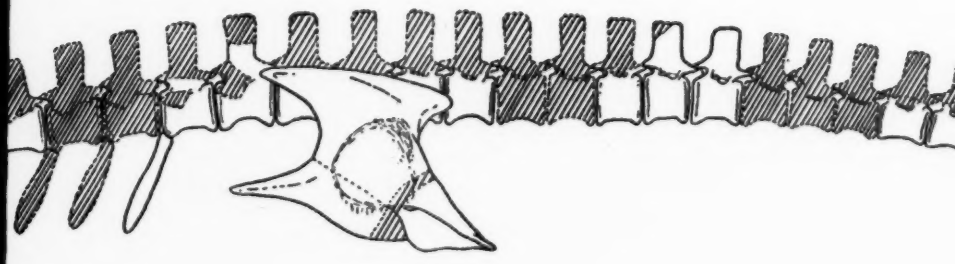


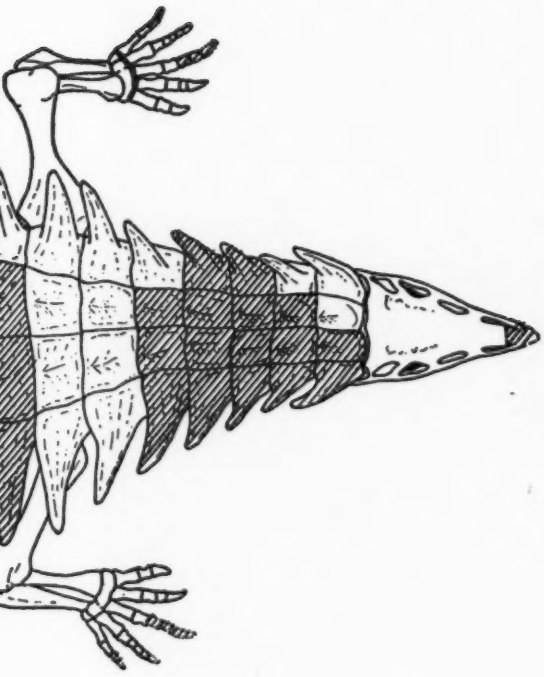
FIG. *13*—*Typothorax meadei* Sawin, n. sp. Vertebral

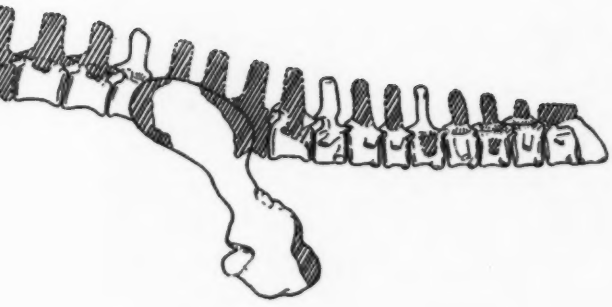


olhorax meadei Sawin, n. sp. Restoration, dorsal view, ×⅛.



rax meadei Sawin, n. sp. Vertebral column and girdles, lateral view, ×⅛.





Sawin, *Typothorax meadei*

central keel and small sculpture peripherally. Some of the smaller button-shaped ossifications are irregularly circular in outline and covered with finely pitted sculpture; others are provided with a small keel, which extends from the margin to the central part of the bone. Over a dozen large (3 by 3 cm.) concavo-convex finely pitted scales possibly protected the proximal portions of the appendages.

TAXONOMY

As noted above, early collections of Triassic vertebrates from Texas and New Mexico showed the presence of two forms, *Typothorax* and *Episcoposaurus*, which were recognizably similar in some respects to pseudosuchians. The specimens were incomplete but differed from phytosaurs in limb proportions and dermal armor. *Typothorax coccinarum* was described by Cope (1875, 1877, 1887) from remains including pitted, transversely long dermal plates, underlain by expanded, bladelike ribs, and also a sigmoidal femur with the long axis of the ends forming an angle of 45° with each other. The plates were compared structurally with those of *Aetosaurus* (Cope, 1887, p. 211). Huene's (1915) revision of the type material shows the median plates with conical eminences in contrast to pyramidal prominences here described for *T. meadei*.

Episcoposaurus horridus was first described from possibly unassociated material from New Mexico (Cope, 1887, p. 213). This included vertebrae, a large straight shafted femur, a humerus, radius, ulna, and dermal plates probably of the lateral caudal armor. Later a new species, *E. haplocerus* (Cope, 1892) was described from Crosby County, Texas, based on "A dorsal and probably two caudal vertebrae; a scapula of the right side; a few fragments of ribs, and about thirty dermal bones." Descriptions of the dermal elements suggest that the genus *Desmatosuchus* (Case, 1920) also collected in Crosby County may be referred to *Episcoposaurus*. Case's specimen is known from more complete material, including a skull and a considerable portion of the dermal and axial skeleton. The skull is remarkably similar in form to that of *Typothorax* in its pseudosuchian characters. If the calcaneum described by Huene (1915) is rightly associated with Cope's type specimen of *Episcoposaurus horridus*, there is but little doubt that the pedes of *Typothorax* and *Episcoposaurus* were also quite similar.

Typothorax coccinarum is characterized by scutes bearing conical eminences. Several large plates in the University of Texas collections show that this animal approached the size of *Episcoposaurus*. The smaller species, *Typothorax meadei*, has bluntly pyramidal, posteriorly placed prominences. These are uniform in character in the largest plates and cannot be a growth phase of conical shapes. This species does not develop a large shoulder horn, and no large horns were found in association with the plates of *T. coccinarum*. The sigmoid shape of the femur and possibly the beaked mandible may serve as differentiating characters.

MORPHOLOGY

A review of the morphological characters of the more primitive thecodonts and an analysis of the trends in the suborder Pseudosuchia show that *Typothorax* may be included as a specialized form. The deep skull, absence of a premaxillary process extending behind and above the external naris, and the lack of a secondary palate or tendencies in that direction as known for the pseudosuchians *Sphenosuchus* and *Ornithosuchus* show that the latter genera are more specialized cranially. *Aetosaurus* is more generalized in lacking the development of a support for the dermal armor on the back of the skull and in having a complete dentition. The armor of *Typothorax* is much more complete. It has a development of lateral spines exceeded only by *Episcoposaurus* and unknown in the more primitive pseudosuchians. Otherwise the shape and proportions of the skull, the presence of an insculpted anteorbital opening and lateral mandibular fenestra, a zone of weakness at the maxillary-premaxillary junction, and the very similar structures of the palates show a

EXPLANATION OF PLATE 34

Typothorax meadei Sawin, n. sp. Mounted specimen in Texas Memorial Museum, Austin, Texas. Total length 3.03 meters. (p. 202)

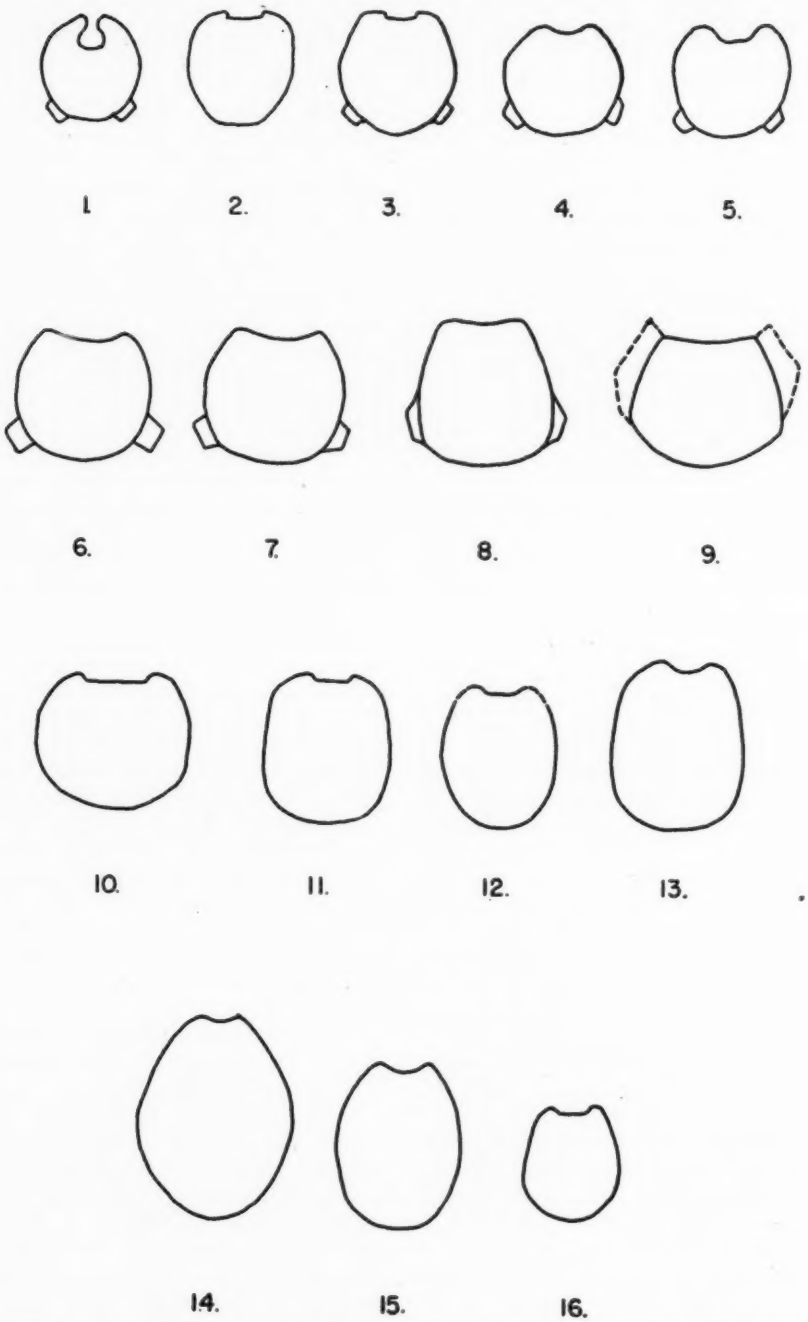


FIG. *14—Typothorax meadei* Sawin, n. sp. Outlines of centra. All views anterior except *2*. *1*, atlas; *2*, axis; *3*, third cervical; *4*, fourth cervical; *5*, fifth cervical; *6*, sixth cervical; *7*, seventh cervical; *8*, eighth cervical; *9*, ninth cervical (transitional); *10*, first (?) thoracic; *11*, fourth (?) thoracic; *12*, fifth thoracic (?); *13*, twenty-third vertebra; *14*, sacral; *15*, seventh caudal; *16*, fourteenth caudal.

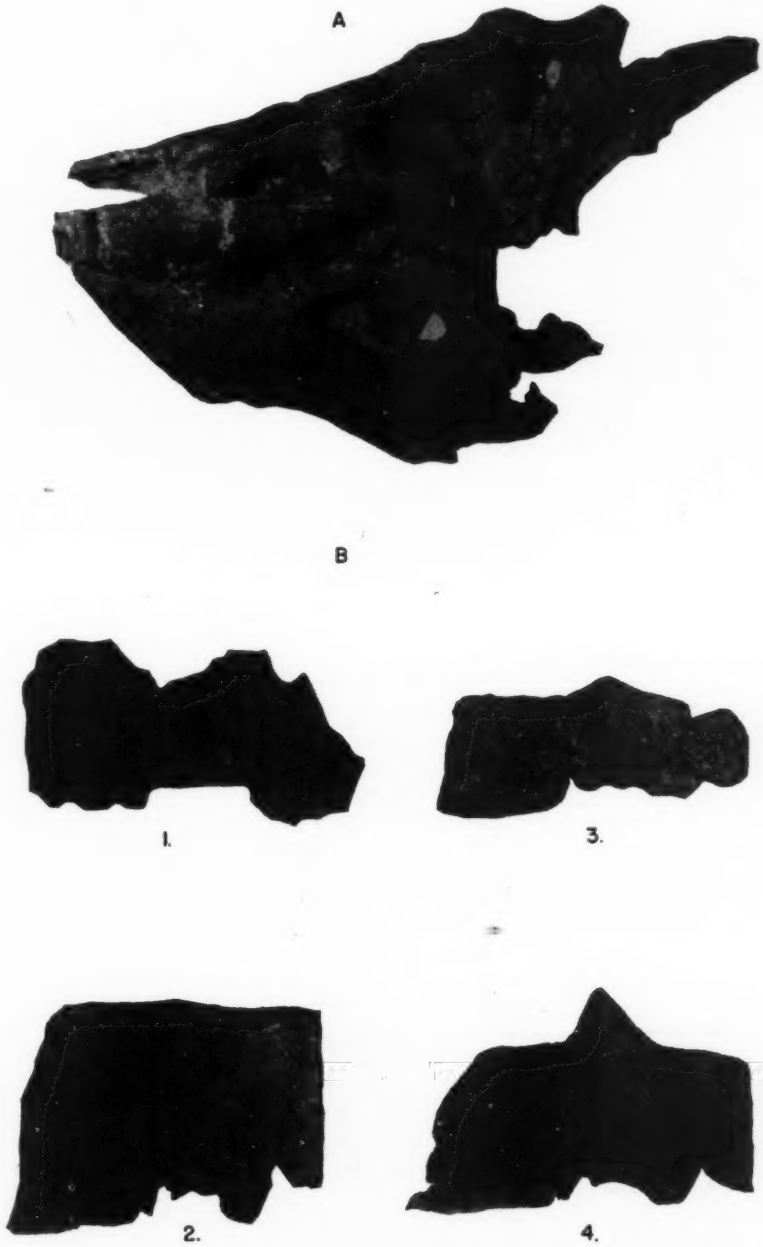


FIG. *15*—*A*, *Typothorax meadei* Sawin, n. sp. Lateral view of skull with spines attached, ×0.3. *B*, Comparisons of central body plates of *Typothorax coccinarum* Cope (*2*, *4*, Univ. of Texas no. 31100-312) and *T. meadei* Sawin, n. sp. (*1*, *3*, Univ. of Texas no. 31100-294); *3* and *4* are tilted at 45°.

Armor

Segment number	Length of spine along anterior edge		Anterior-posterior thickness at Base of spine		Anterior-posterior length of plates at lateral articulation		Anterior width of median plates		Posterior width of median plates	
	R	L	R	L	R	L	R	L	R	L
1	*	9.0	*	4.5	*	5.5	*	2.1	*	3.45
2	*	7.25	*	4.32	*	*	*	*	*	*
3	*	*	*	*	*	*	*	*	*	*
4	*	*	*	*	5.7 est.	*	3.1 est.	*	3.75	*
5	*	10.45	*	4.52	*	*	*	*	*	*
6	11.0 est.	11.6	5.1	5.1	6.5 est.	6.35	*	5.85	6.8	6.5 est.
7	10.9	11.1 est.	5.6	5.3	6.3	6.3	7.4 est.	5.9	*	6.9
8	*	11.2	*	6.1	*	6.4 est.	*	*	*	*
9	10.4 est.	*	5.2	*	7.05	7.0 est.	11.15	11.00 est.	12.0	12.2
10	9.85	10.3	5.6	5.4 est.	6.4 est.	*	13.5 est.	*	14.3	*
11	*	*	*	*	*	6.5 est.	*	13.1 est.	*	*
12	9.5	9.5 est.	5.9	5.5	6.4	*	15.3	*	15.0	*
13	*	9.0	*	6.2	6.4	6.4 est.	16.4	15.2	15.5	14.7 est.
14	8.65	9.2	5.2	5.5	*	6.8 est.	*	15.9	*	15.6
15	*	8.8	*	5.8	6.4 est.	*	16.4 est.	*	15.5 est.	*
16	*	*	*	*	6.35	*	15.9	*	15.7	*
17	*	*	*	*	6.5 est.	*	16.0	*	15.1	*
18	8.2	8.8	5.1	5.1	6.5 est.	*	15.1	*	13.7	13.7 est.
19	8.65	9.0 est.	5.7	5.9 est.	7.0	7.3	13.9	13.5	11.35	*
20	*	8.7	*	5.9	7.1	*	11.6	*	9.95	*
21	8.9 est.	8.9 est.	5.9	5.8	7.1 est.	*	*	*	*	*
22	8.4	9.0 est.	5.9	6.1	6.7	*	*	*	*	*
23	7.5	8.5 est.	5.65	5.4	*	*	*	*	*	*
24	7.6	7.6 est.	5.4 est.	5.6 est.	7.6 est.	*	*	*	*	*
25	7.3	7.7	5.4	5.4 est.	*	*	*	*	*	*
26	*	*	*	*	*	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*	*
28	*	*	*	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*	*	*	*
30	*	*	*	*	*	*[1]	*	*	*	*

* Restored.
[1] Length of caudal plates at median dorsal line.

Armor—(*continued*)

Segment number	Length of spine along anterior edge		Anterior-posterior thickness at base of spine		Anterior-posterior length of plates at lateral articulation
	R	L	R	L	R
31	5.2	5.2 est.	5.4	5.4 est.	6.8
32	4.6	4.7	4.9	5.0	6.9
33	4.3	2.9	4.05	3.5	6.5
34	4.6	2.3	4.4	3.1	6.45
35	3.05	3.8	3.6	4.1	5.6
36	2.65	3.0 est.	3.0	3.7	6.0
37	3.8 est.	3.1	3.9	3.9 est.	5.9

Armor—(*continued*)

Segment number	Anterior-posterior thickness at base of spine		Anterior-posterior length of plates at lateral articulation	Length of lateral caudal plates		Height of lateral caudal plates		Length of basal caudal plates		Width of basal caudal plates	
	R	L	R	R	L	R	L	R	L	R	L
38	3.8	*	5.3	5.5	5.6	3.42	3.5	5.2	5.8	4.0	3.7
39	3.4	2.9	4.9 est.	5.3	5.2	*	3.1	5.4	5.7	3.25	3.3
40	3.5	3.5 est.	5.2	5.0	5.2	3.9	*	5.2	5.3	2.7	2.6
41	*	3.5 est.	4.8								
42	3.5	3.5	4.7 est.								
43	3.0	*	*								
44	2.2 est.	2.2 est.	3.9								
47–52	Distorted.....										

definite relation in the two forms. These similarities extend to the known parts of the postcranial skeleton, which are parallel to the crocodilian in many respects in both animals. Von Huene (1921) figures the pes of *Aetosaurus* with a well developed tuber to the calcaneum and other tarsal structures comparable to those of *Typothorax;* in the manus, one of the proximal carpals is similar. It may be noted that the absence of details

on Huene's specimens may be due to the immaturity of the animals, and the slight variations in proportions of the limb bones when compared to those of *Typothorax* may also be due to age differences.

Euparkeria differs from *Typothorax* in several respects which show a more definite trend in the attainment of crocodiloid characters. The skull seems to be more primitive than that of *Aetosaurus* and may well be a stage of form leading to *Aetosaurus* and greatly in advance of the Eosuchian condition as exemplified by *Youngina*. The premaxillary region has no zone of weakness and is produced backward but does not as fully delineate the nasal opening as in *Sphenosuchus*. The anteorbital fenestra of *Euparkeria* is insculpted and of much the same proportions known in *Typothorax;* the more complete but tenuous postorbital-jugal and jugal-quadratojugal bars are similar to the preserved parts of the temporal arcade of the latter. The pectoral girdles are dissimilar, but the unossified condition in *Euparkeria* and size differences may account for the variation in form. In *Typothorax* muscular processes are more prominent, there is a more pronounced shelf beneath the glenoid, and the neck of the bone is more constricted.

As noted above, characters common to *Typothorax* and other pseudosuchians which are not apparent in the ancestral eosuchians include an anteorbital fenestra, reduction in size and proportions of the elements of the temporal arcade, reduction in the number of teeth and the tendency toward the formation of a beak, and loss of elements in the skull roof. A morphological series of skulls would include *Youngina*, *Euparkeria* and *Aetosaurus* as stages leading to *Typothorax*. It is probable that the Connecticut valley genus *Stegomus* may show intermediate characters bridging the gap between the relatively unspecialized smaller pseudosuchians and *Typothorax*.

The contrast in size between the manus and pes of *Typothorax* is notable, leaving no doubt of this animal's origin from ancestors with bipedal tendencies. Development of the crocodilian type of tarsus and the reduction of the fifth digit may be noted in *Ornithosuchus*, *Euparkeria*, *Aetosaurus* and *Typothorax* but the manus varies considerably from the crocodilian form in all of these genera. Schaeffer (1941) derives the crocodilian tarsus from the generalized condition in *Labidosaurus* through *Youngina* by way of *Chasmatosaurus*, and further indicates a close resemblance of the tarsus of *Protosuchus* to *Aetosaurus*. Brown's (1933) description of *Protosuchus* shows this Lower Triassic form to be well advanced along the lines of crocodilian evolution in the bridging of the palate, the structure of the girdles and in the form of the carpals and tarsals. Thus the development of true crocodilian characters was relatively complete early in Triassic time and the many similarities in form noted for the pseudosuchians represent cases of parallelism.

The animals collected from the Otis Chalk region fail to show the extensive development of the shoulder spines characteristic of *Episcoposaurus*, but several fragmentary specimens in the collection from Crosby County, Texas definitely represent the larger type. The possibility of sexual dimorphism is suggested by such a difference, but no known analogous case exists in recent reptiles. It is probable that the shorter spined forms represent more primitive animals. If *Aetosaurus* is regarded as ancestral, the derivation of the *Typothorax* armor from an animal of similar characters but with a tendency toward spinescence may be postulated. Such a form may be represented by a reptile described by Case (1932), suspected of having parasuchian affinities. Its general appearance is similar to that known for *Typothorax* except that the spines of the lateral plates are even shorter. *Stegomus*, the Newark pseudosuchian would seem to take a position between that of Case's animal and *Aetosaurus* in a series showing increasing complexity of spine form.

ASSOCIATIONS AND HABITS

Animals found at the same level at the Otis Chalk locality include phytosaurs of the genera *Promystriosuchus*, *Brachysuchus*, and *Angistorhinus; Buettneria; Coelophysis; Trilophosaurus;* ganoid scales and Unios. These were aquatic or semiaquatic with the exception of *Trilophosaurus* and *Coelophysis*, and the concentration of remains in clay deposits is suggestive of swamp conditions. Dissociated skeletal parts are most commonly found indicating displacement due to water action and struggles of entrapped

animals. The finding of two entire skeletons of *Typothorax* amidst the scattered remains of phytosaurs and amphibians leads to suspicions, supported by anatomical evidence, that this reptile was a necrophile. Certainly the teeth of this pseudosuchian were not adapted to predaceous habits and the heavy and complete armor predicate a passive mode of life. Competitors for food include the phytosaurs and the buettneriomorph amphibians; these two groups probably restricted *Typothorax* to a shallow water and swamp environment. This animal probably could not successfully compete with either group for living prey.

SUMMARY

Typothorax meadei, n. sp., a pseudosuchian reptile from the Dockum Triassic of Texas is described and compared with related forms.

Anatomical characters include the following:

1. A short, probably diapsid skull retaining the post parietals and possibly the tabulars. The palate is primitive

Specializations include an edentulous anterior part of the mandible probably enclosed by a horny beak and the development of a laterally placed upper temporal opening and articular surfaces for nuchal armor. Anteorbital and mandibular fenestrae are present.

2. A complete dermal armor with lateral spines.

3. No intercentra in presacral vertebrae. Column well differentiated regionally.

4. Limb bones and pes crocodiloid, with muscular processes and expanded ends of bones developed in relation to burden of armor. The manus and the girdles probably retain a primitive pseudosuchian pattern and show few crocodilian characters.

The structure of *Typothorax* and the closely related *Episcoposaurus* place these genera in the family Stagonolepidae of the suborder Pseudosuchia.

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ENDOLOBUS FROM THE GREENBRIER LIMESTONE OF PENNSYLVANIA

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ABSTRACT—Meek and Worthen's genus *Endolobus* is discussed, and *E. greenbrierensis*, n. sp., is described from the Upper Mississippian Greenbrier limestone near Uniontown, Pennsylvania. The new species resembles rather closely *E. spectabilis* (the genotype) and *E. greenensis* of the Chester of Illinois and Indiana, respectively.

THE Greenbrier limestone, which was named from exposures along the Greenbrier River in West Virginia, extends over a considerable area in southern Pennsylvania, western Maryland, northern West Virginia and Virginia. In Pennsylvania it lies between the Pocono sandstone below and the Mauch Chunk shale above, and is now considered to be of "post-Ste. Genevieve" age (Wilmarth, 1938, p. 867). In general, the Greenbrier consists of massive dark-blue limestone, commonly cherty in the lower part, purer in the midportion, and becoming shaly toward the top, where it passes without any noticeable break into the succeeding formation (Bassler, 1909, p. 274). In the type area, in southeastern West Virginia, the Greenbrier limestone is stated to attain a thickness of as much as 1,700 feet (Campbell, 1896, p. 3), but it thins to the north and in the vicinity of the West Virginia-Pennsylvania boundary has a thickness of only about 80 to 150 feet (Hennen and Reger, 1913, p. 383). At the latter locality it consists chiefly of hard dark-gray limestone with some sandy beds near its base and some red shale near its top.

The calcareous portions of the Greenbrier contain an abundance of well-preserved marine fossils, of which the more common forms are blastoids, crinoids, brachiopods, and pelecypods. However, insofar as we have been able to ascertain, not a single cephalopod has been described from the entire formation, and only two, "*Orthoceras* aff. *epigrus*" and "*Orthoceras* sp." have been listed from it (Girty, 1923, p. 453; 1926, p. 856). Therefore the discovery of three large coiled nautiloids in the Greenbrier seems to merit special consideration.

The specimens to which we refer came from two quarries near Uniontown in southwestern Pennsylvania. All of them are preserved in dark-gray fine-grained limestone, and they seem to represent only one species. They were found in association with numerous bryozoans, brachiopods, and crinoid stems, and a few blastoids, crinoid calyces, gastropods, and fish teeth, but no other cephalopods.

Clearly these specimens belong in Meek and Worthen's genus *Endolobus*, of which the type species is *Nautilus spectabilis* Meek and Worthen of the Chester of Illinois. The chief characteristics of this genus are a subglobular tarphyceraconic conch with depressed subelliptical whorls, broad deep hyponomic sinus, wide umbilicus, large low rounded lateral nodes, almost straight sutures (except for a dorsal lobe resulting from slight involution of the conch), and a small subcentral orthochoanitic siphuncle. As noted by Miller, Dunbar, and Condra (1933, pp. 194–195), representatives of this genus are of widespread occurrence in both this country and Europe, and stratigraphically they range from the Upper Mississippian to the Middle Permian. The Greenbrier species is, however, closely similar to only the genotype and to another late Mississippian species, *E. greenensis* (Miller and Gurley) of southwestern Indiana. Therefore, it is certainly in harmony with a "post-Ste. Genevieve" or Chester age for the containing beds.

ENDOLOBUS GREENBRIERENSIS
Miller and Collins, n. sp.
Plate 35, figures 1, 2

It seems clear that the three specimens

we are studying are not referable to any described species. One of them is considerably better than the other two, and therefore we are designating it as the holotype. Although this individual is an internal mold that is not very well preserved and is somewhat distorted, it elucidates most of the more significant characters of the conch. The adoral quarter-volution is non-septate and presumably therefore represents living chamber.

The conch is moderately large, is subglobular in shape, is rather rapidly expanded orad, and consists of at least two full volutions. The maximum diameter of the holotype measures about 132 mm. The whorls are subelliptical in cross section, being broadly rounded ventrally, more narrowly rounded laterally, and in general broadly rounded dorsally though along the median portion of the dorsal side there is a rather narrow and shallow impressed zone. The ventral side of the conch is more highly arched than is the dorsal. Near the junction of the phragmacone and the living chamber, the conch of the holotype is about 65 mm. wide and 48 mm. high. The living chamber is at least a quarter of a volution in length—that of the holotype is not complete adorally.

The umbilicus is large, so the lateral zones of the inner volutions of the conch are visible. The umbilical shoulders are indefinite, but it can be said that the diameter of the umbilicus is something like two-thirds that of the conch. Although the inner portions of the holotype are not at all well preserved, it seems reasonably certain that the umbilicus is perforate and that the umbilical perforation is fairly large.

On the narrowly rounded lateral zones of the conch there is a row of large, low, rounded nodes. It is estimated that in the outer volution of the holotype there were about a dozen of these nodes on each side of the conch. On the adoral portion of the holotype there are faint transverse markings that may represent growth lines; they suggest that there was a broad rounded ventral or hyponomic sinus.

The camerae are short, and it is estimated that there are some 30 of them to a volution. The external sutures are almost straight and directly transverse, though those of the holotype are very slightly sinuous, possibly as a result of the distortion that the specimen has obviously undergone during preservation.

The siphuncle is exposed near the adapical end of the outer volution of the holotype. It is rather small, is located considerably closer to the venter than the dorsum, and is composed of segments that are more or less cylindrical but may be somewhat expanded within the camerae. At this place the conch is about 45 mm. wide and 25 mm. high, and the siphuncle is some 5 mm. from the venter and some 3 mm. in diameter.

One of the paratypes is of the same general size and shape as the holotype, but it is so crushed and distorted that precise measurements of it would have little significance. This specimen also appears to represent part of the living chamber as well as the phragmacone, and it bears similar lateral nodes. The other paratype, which is largely if not entirely septate, represents one side of about a quarter of a volution of a conch that was slightly larger than the holotype and may not be conspecific with it. The external sutures of this specimen are nearly straight and directly transverse, but the internal sutures form a deep V-shaped but narrowly rounded dorsal lobe.

Remarks.—Of all the representatives of the genus *Endolobus* that have been illustrated and described, this species seems to be closest to the genotype, *E. spectabilis* (Meek and Worthen) of the Chester of Illinois. However, it can be readily distinguished from that species by means of its relatively short camerae, essentially straight sutures, and subventral siphuncle. *E. greenensis* (Miller and Gurley) of the Chester of Indiana also seems to be rather similar; it has short camerae, as does *E. greenbrierensis*

EXPLANATION OF PLATE 35

FIGS. *1, 2*—*Endolobus greenbrierensis*, n. sp. Ventral and lateral views of the holotype, from the Greenbrier limestone southeast of Uniontown, Pennsylvania, ×1. (p. 239)

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1

Miller and Collins, *Endolobus*

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but its sutures are sinuous and its siphuncle is located approximately midway between the center and the venter.

The illustrations which accompany this report are photographs retouched by Howard Webster. Acknowledgment is also due to David M. Seaman for the loan of the paratypes.

Occurrrence.—Greenbrier limestone near Uniontown in southwestern Pennsylvania. The holotype was found by Leigh R. Collins in North Union Township quarry, 1½ miles southeast of Hopewood; whereas the paratypes were collected by David M. Seaman in the J. V. Thompson quarry about half a mile east of the Summit Hotel on top of Chestnut Ridge about 8 miles east of Uniontown—the two quarries from which these specimens came are about 3 miles apart, and both are along U. S. Highway 40 on opposite sides of the ridge.

Types.—State University of Iowa, 8133 (holotype); and Carnegie Museum, 25784 and 25785 (paratypes).

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CONODONTS FROM THE SHEFFIELD FORMATION OF NORTH-CENTRAL IOWA

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ABSTRACT—A well preserved but limited conodont fauna is illustrated and described from the type area of the Sheffield formation in north-central Iowa. The general aspect of this conodont assemblage, together with the notable abundance of representatives of the genus *Icriodus* indicate that the Sheffield is most probably Upper Devonian in age.

THE Sheffield formation is sparsely fossiliferous, and due to this general lack of paleontological evidence, it has variously been referred to the Upper Devonian or to the Lower Mississippian. The name Sheffield was proposed by Fenton in 1919 for shales which occur below the Cerro Gordo member of the Hackberry shale. Later, Thomas (1925, p. 116, footnote) revised this definition through the following comments:

> In connection with the term *Sheffield* attention should be called to the fact that in . . . 1919, the name Sheffield was applied to the plastic blue shale which underlies the marly fossiliferous zones of the Cerro Gordo sub-stage at Rockford . . . and elsewhere north and east of Sheffield. Fenton was doubtless under the impression that the shales at Sheffield were identical with those of Devonian age at Mason City and Rockford, being apparently misled by Williams' error in describing and mapping the shales at Sheffield as Upper Devonian in the Franklin county report. However, the beds at Sheffield are Kinderhook according to Van Tuyl's evidence and the name as employed by him seems appropriate. Since the name Sheffield for obvious reasons is unavailable for the Upper Devonian shales, the name *Juniper Hill* is here offered for that formation.

In this way the term Sheffield has been generally accepted as primarily limited to the shales that are exposed principally in the vicinity of Sheffield but are known to occur at one or two other localities.

Among the better exposures of the Sheffield formation in the type area is a section in the clay pit of the Sheffield Brick and Tile Company, just south of the town of Sheffield, near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa (Van Tuyl, 1925, p. 101). Here, the Sheffield is a blue-gray, dense, plastic marine shale with occasional interbedded thin layers of brown dolomite and limestone. For the present report, samples of shale were collected from the bottom of the clay pit and upward at intervals of 3 feet. The horizon about 15 feet above the bottom of the pit and 12 feet below the lowest dolomite layer proved to be the only zone yielding conodonts in appreciable numbers. Even here, however, conodonts are by no means abundant, and it was necessary to boil and reduce a considerable amount of shale in order to secure the fauna.

This conodont assemblage which we have thus secured from the Sheffield formation is unusual in that only six genera are represented and the number of species is not great. This limited fauna presents a contrast to most Upper Devonian or Lower Mississippian assemblages, for during those times conodonts seem to have been exceptionally diversified and very abundant. Most of the conodont genera represented in our collection do not seem to be particularly significant in regard to either an Upper Devonian or Lower Mississippian age determination. However, the genus *Icriodus*, which is the most abundant generic form in our assemblage, appears to be important on the basis of its known stratigraphic distribution. This genus was given special study by Branson and Mehl in 1938, and they state (p. 159) that

> *Icriodus* is one of the most sharply defined and distinctive of the Devonian forms. It is one of the several genera that range through Upper Devonian strata but fail to appear in the Mississippian.

The genus seems to have no close relatives in Mississippian strata, nor does it appear to have had any distinctive predecessors in the Lower Devonian. However, *Icriodus* is

widespread in the upper portion of the Middle Devonian and has been recorded also from many Upper Devonian zones. *Icriodus* occurs in the Olentangy and the Silica shales of Ohio and in the New Albany shale and Jeffersonville limestone of Indiana. It has been reported from the Grassy Creek shale, the Snyder Creek shale, the Mineola limestone, and the Callaway limestone, all of Missouri. The Genesee and Genundewa beds of New York contain representatives of *Icriodus*. In Iowa, in addition to the Sheffield formation, the genus *Icriodus* has been reported from the Sweetland Creek shale of the southeastern part of the State, and it occurs also in an unnamed Upper Devonian shale which overlies the Cedar Valley limestone and is exposed 1½ miles northeast of North Liberty, Iowa. *Icriodus* has been reported from the Middle and/or Upper Devonian of Minnesota, Michigan, Oklahoma, and Arkansas as well as other areas.

It should be stated, however, that representatives of *Icriodus* are also known to occur in the Louisiana limestone of Missouri. This formation has been referred to both the Upper Devonian and the Lower Mississippian. In 1943, Williams discussed in detail the fauna of the Louisiana limestone and concluded that it is Kinderhook in age. Among other fossils, representatives of the goniatite genera *Protocanites?* and *Imitoceras* were described by Williams. Primitive specimens of the latter genus are known from the Upper Devonian of Europe, but in America none is known to occur below the Lower Mississippian, unless the Louisiana should prove to be Upper Devonian. It should be stated in this connection, that Cooper *et al.* (1942) classed the Louisiana limestone, the Sweetland creek shale and the Grassy Creek shale as "Devonian or Mississippian" and regarded the Sheffield as Devonian stating (p. 1780) that it "seems clear that the Sheffield is of Cassadaga age and not Kinderhook as claimed by some." Laudon (1935, p. 246) stated in regard to the Sheffield that "there is little question but that the fauna should be referred to the late Upper Devonian."

Icriodus does not seem to appear in undoubted Mississippian strata but it is widespread and well developed in Middle Devonian and Upper Devonian formations. The premise that an abundant and varied *Icriodus* fauna is as diagnostic as any known conodont assemblage for a Middle or Upper Devonian age is probably valid, though the presence of at least one species of *Icriodus* in association with *Imitoceras* casts some doubt on the exact stratigraphic limits of both genera.

In regard to other conodont forms, it should be mentioned that *Prioniodus bellulus* Youngquist, which occurs in the Sheffield, was first described from an Upper Devonian shale near Middle Amana in east-central Iowa. Also, the small-plate species of *Polygnathus*, such as *P. brevilamina* Branson and Mehl and *P. iowaensis*, n. sp., which are prominent among the polygnathids of our Sheffield collection, have a closely related form in *P. angustidisca* Youngquist of the Middle Amana beds. These latter beds contain the well known Devonian goniatite *Manticoceras*, the genotype of which came from the Naples of New York.

In summary it can be said that the conodont assemblage of the Sheffield formation appears to be somewhat aberrant since it presents a rather limited variety of generic forms during a time when conodont faunas were particularly diversified. It is dominated by the genera *Hindeodella* and *Icriodus*. This notable abundance of representatives of the latter genus in the Sheffield fauna together with the general aspect of the conodont assemblage indicate that the Sheffield formation is most probably referable to the Upper Devonian.

Acknowledgments are due to Dr. M. A. Stainbrook and Dr. H. Garland Hershey who, during field investigations for the Iowa Geological Survey, first sampled and secured conodonts from the Sheffield formation and later brought this occurrence to our attention. In addition, excellent laboratory facilities have been generously supplied by the Geology Department of The State University of Iowa and we wish to express our appreciation to Professors A. C. Trowbridge and A. K. Miller for the many helpful suggestions that have been given us during the progress of this study.

All specimens described in this report were procured in the clay pit of the Sheffield

Brick and Tile Company, near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa. The illustrations are photographs, which were retouched by Mr. Howard Webster of Iowa City, and all are ×40. The collection has been placed in the repository of the Geology Department at The State University of Iowa.

SYSTEMATIC PALEONTOLOGY

ANGULODUS COMPRESSUS
Youngquist and Peterson, n. sp.
Plate 36, figure 6

The bar of this species is strongly compressed laterally to nearly a bladelike form. It is sharply keeled and there is no aborally extended process beneath the cusp and there is no escutcheon. The denticles are deeply "inserted"—more so posterior to the cusp than anterior to it. The cusp is oval in cross section, the denticles are circular. One or two small "germ" denticles are present between the adjacent erupted denticles. The entire specimen is up-arched as well as slightly flexed laterally. The cusp as well as the denticles are slightly inclined inward and posteriorly. The posterior bar limb of the figured specimen is incomplete.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4060.

ANGULODUS? sp.
Plate 36, figure 5

The bar is flexed in two planes, is flattened laterally, and aborally there is a small keel, which becomes progressively prominent posteriorly. The denticles are deeply "inserted" and in some instances one or two small "germ" denticles occur between adjacent erupted denticles. These erupted denticles are circular in cross section and all incline posteriorly as well as slightly inward in varying amounts.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Repository.—State Univ. Iowa, 4061.

DIPLODELLA sp.
Plate 36, figure 4

From both the original generic description given by Ulrich and Bassler (1926) and the revised description by Branson and Mehl (1934), it appears that our Sheffield form is clearly referable to the genus *Diplodella*. The bar is thick, somewhat sharpened aborally, and expands orally to carry two rows of closely spaced but discrete, rounded denticles. The outer (figured) side of the bar has slightly smaller denticles than the inner side. The cusp is roughly triangular in cross section, the apex of the triangle being on the outer side. The bar and cusp are closely fused and the amber-colored bar material encroaches a short distance upon the cusp, particularly on the inner side.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Repository.—State Univ. Iowa, 4062.

HINDEODELLA ACULEATA Huddle
Plate 38, figure 9

Hindeodella aculeata HUDDLE, 1934, Bull. Am. Paleontology, vol. 21, no. 72, pp. 14, 27, 43, pl. 4, figs. 19–21, pl. 5, figs. 2, 3.
Hindeodella aculaeta HUDDLE, 1934, idem, p. 40.
Hindeodella aculeata Huddle. COOPER, 1939, Jour. Paleontology, vol. 13, pp. 389, 419, pl. 46, fig. 36.
Hindeodella aculeata Huddle. COOPER, 1943, Jour. Paleontology, vol. 17, p. 170, pl. 28, fig. 29.
Hindeodella aculeata Huddle. COOPER, 1945, Jour. Paleontology, vol. 19, p. 613, pl. 84, figs. 7, 9.

The bar is only gently bowed and up-arched. It is laterally compressed and on the aboral surface the bar is sharpened to form a median keel, which is interrupted only by the presence of a very small excavation beneath the cusp. Near the aboral margin of the bar, on both the inner and outer lateral surfaces, there is a slight ridgelike thickening. The denticles are in an alternating series wherein two to four (usually three) small erupted denticles occur between adjacent large denticles. All the denticles and the cusp are deeply "inserted" and are inclined posteriorly at a uniform angle. The cusp is slightly compressed laterally but both the large and small denticles are essentially round. The precision and regularity of denticle shape and the manner and degree of insertion are noteworthy in this Sheffield form.

Through a typographical error, the heading of the original specific description of this species carries the spelling as *Hindeodella*

aculaeta. However, in five other places in the report, the spelling *H. aculeata* is used and this is assumed to be correct.

Occurrence.—Middle and upper New Albany shale of Indiana, a "Bushberg-Hannibal" horizon in Oklahoma. a "Lower Mississippian" shale in Alberta, an "Upper Devonian" shale in Montana, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4063 (figured specimen) and 4064 (unfigured specimen).

HINDEODELLA ACUTA Branson and Mehl
Plate 38, figures 7, 8

Hindeodella acuta BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 3, p. 196, pl. 14, fig. 8.
Hindeodella acuta Branson and Mehl. COOPER, 1939, Jour. Paleontology, vol. 13, pp. 389, 419, pl. 46, figs. 15, 23, 29.
Hindeodella acuta Branson and Mehl. BRANSON and MEHL, 1944, *in* SHIMER and SHROCK, Index fossils of North America, p. 241, pl. 93, fig. 47.
Hindeodella acuta Branson and Mehl. BRANSON and MEHL, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, p. 162.

The denticles of this form originate deep within the bar, are round or only slightly compressed laterally and incline posteriorly. Two or three unerupted or only slightly erupted "germ" denticles occur between adjacent large denticles. The bar is gently arched and bowed, is flat laterally but aborally it bears a distinct keel. The anterior bar extension is sharply flexed laterally and is also denticulate. The cusp is large, compressed laterally, and deeply "inserted" into the bar.

Occurrence.—The Grassy Creek shale of Missouri, a "Bushberg-Hannibal" horizon in Oklahoma, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4065 (fig. 7) and 4066 (fig. 8).

HINDEODELLA LAMBTONENSIS Stauffer
Plate 38, figure 6

Hindeodella lambtonensis STAUFFER, 1938, Jour. Paleontology, vol. 12, pp. 412, 428, pl. 50, figs. 2, 5, 8, 13, 14, 17, 20, 25, 28, 31.
Hindeodella lambtonensis Stauffer. YOUNGQUIST, 1945, Jour. Paleontology, vol. 19, p. 361, pl. 55, fig. 10.

The bar is strongly compressed laterally to the extent of being almost bladelike. It is gently bowed and aborally bears a small keel. There is no excavation beneath the cusp. The denticles originate deep within the bar, are somewhat compressed laterally, and are confluent with one another as they erupt from the bar. The denticles are subequal in size, but there is a distinct alternation of large individuals with small ones. The cusp is decidedly larger than any of the denticles, but it too is compressed laterally.

Occurrence.—Olentangy shale of Ohio, the "Olentangy" of Ontario, an Upper Devonian shale near Middle Amana, Iowa, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotype.—State Univ. Iowa, 4067.

HINDEODELLA MILLERELLA
Youngquist and Peterson, n. sp.
Plate 38, figures 1–5

The bar is stout, laterally compressed, gently bowed, and slightly to moderately arched. Near its aboral margin, the bar narrows to form a pronounced keel, which is in an aboral-median position. This keel persists the length of the specimen, there being no aboral excavation beneath the cusp. The denticles are somewhat irregular both as to size and spacing, but nearly all are essentially circular in cross section—a few are slightly flattened on the inner side. A number of "germ" denticles are visible in the bar when it is viewed by means of transmitted light. These "germ" denticles number from one to three between adjacent large erupted denticles. Only a very few of these small denticles are erupted, but their presence serves to place these specimens definitely in *Hindeodella*. The cusp is large, circular in cross section, and continues anteriorly as an anticusp or anterior bar extension, the extent of which cannot be determined from any of the syntypes available. Both the cusp and the denticles are inclined posteriorly in varying degrees, and all originate deep in the bar. Some of the denticles approach but do not quite equal the cusp in size. This species differs from most hindeodellids in the large size of the erupted denticles, the relatively small number of "germ" denticles present, and in the lack of denticle-crowding on the bar.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Syntypes.—State Univ. Iowa, 4068 (fig. 1), 4069 (fig. 2), 4070 (fig. 3), 4071 (fig. 4), and 4072 (fig. 5).

HINDEODELLA sp.
Plate 36, figure 13

The bar is strongly compressed laterally. The denticles are deeply "inserted" and incline backwards at an angle which becomes progressively greater posteriorly. Between adjacent large erupted denticles, one or two small erupted denticles or unerupted "germ" denticles are present. Aborally, the bar is tapered to form a sharp keel, which persists throughout the length of the specimen. This form appears to be close to such other laterally compressed specimens as *H. compressa* Huddle.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Repository.—State Univ. Iowa, 4073.

ICRIODUS ALTERNATUS Branson and Mehl
Plate 37, figures 18, 19, 21

Icriodus alternatus BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 3, pp. 225–226, pl. 13, figs. 4–6.

Icriodus alternatus Branson and Mehl. BRANSON and MEHL, 1938, Jour. Paleontology, vol. 12, pp. 156, 158, 161, pl. 26, figs. 4–6.

Icriodus alternatus Branson and Mehl. GROHSKOPF, CLARK and ELLISON, 1943, Missouri Geol. Survey and Water Res. 62nd Bienn. Rept., appendix 4, p. 15, pl. 2, figs. 3, 6.

Icriodus alternatus Branson and Mehl. BRANSON and MEHL, 1944, *in* SHIMER and SHROCK, Index fossils of North America, p. 245.

Icriodus alternatus Branson and Mehl. MEHL and QUIGLEY, and QUIGLEY, respectively, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, pp. 153, 158, pl. 26, figs. 1–5.

Icriodus alternatus Branson and Mehl. CLARK, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, p. 155.

Icriodus alternatus Branson and Mehl. BRANSON and MEHL, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, pp. 157, 163, pl. 28, figs. 11–13 [misprinted as "11, 13"].

This species is somewhat variable but it retains the feature of median denticles alternating in transverse alignment with those of the lateral rows. About seven to nine denticles are present in the median row, about five to eight occur in each lateral row. The posteriormost denticle of the median row is usually pronouncedly discrete, pointed, and inclined backwards at a moderate angle. Aborally, there is a groove the entire length of each specimen. The flaring of the aboral margins is not pronounced and is confined to the posterior third of the conodont.

Occurrence.—The Grassy Creek shale, the Snyder Creek shale, and the Fortune formation of Missouri, the Sylamore sandstone of Missouri and Arkansas, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4074 (fig. 18), 4075 (fig. 19) and 4076 (fig. 21).

ICRIODUS CIRCULARIS
Youngquist and Peterson, n. sp.
Plate 37, figure 15

In long axis this species is essentially straight except for a slight lateral curvature near the anterior end. Five discrete denticles are present in each lateral row; about seven denticles are present in the median row—the posteriormost denticle is unusually large and is inclined backwards. Unlike all other representatives of *Icriodus* in the collection at hand, this species is very markedly flared aborally. The diameter of this subcircular excavation is about two-thirds the length of the entire specimen. The circular continuity of this depression is interrupted only by the presence of a small narrow groove which extends from the anterior end of the specimen to the major excavation.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4077.

ICRIODUS EXPANSUS Branson and Mehl
Plate 37, figures 5–7, 10, 20

Icriodus expansus BRANSON and MEHL, 1938, Jour. Paleontology, vol. 12, pp. 156, 158, 160–161, pl. 26, figs. 18–21.

Icriodus expansus Branson and Mehl. STAUFFER, 1938, Jour. Paleontology, vol. 12, p. 430, pl. 52, figs. 12, 14, 16, 19, 20, 25, 33, 35.

Icriodus expansus Branson and Mehl. STAUFFER, 1940, Jour. Paleontology, vol. 14, p. 425, pl. 60, figs. 40, 47, 48, 59–64, 70, 71.

Icriodus expansus Branson and Mehl. GROHSKOPF, CLARK and ELLISON, 1943, Missouri Geol. Survey and Water Res. 62nd Bienn. Rept., appendix 4, pp. 15–16, pl. 2, figs. 1, 2, 5, 8, 11, 13.

Icriodus expansus Branson and Mehl. BRANSON and MEHL, 1944, *in* SHIMER and SHROCK, Index fossils of North America, p. 245, pl. 94, fig. 63.
Icriodus expansus Branson and Mehl. MEHL and QUIGLEY, and QUIGLEY, respectively, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, pp. 153, 158, pl. 26, figs. 7–9.
Icriodus expansus Branson and Mehl. CLARK, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, p. 155.

The denticles are arranged in three longitudinal rows. Each lateral row consists of about eight rounded discrete denticles; the median row of denticles is subdued but includes about eight small denticles in addition to the two larger denticles which terminate the posterior end of the row. As was pointed out by Branson and Mehl (1938, p. 161), transversely the rows of denticles are not in line but neither are they in alternating series. Aborally, there is a narrow groove anteriorly, but posteriorly this excavation becomes broad and very deep.

Occurrence.—Mineola limestone, the Fortune formation, the Snyder Creek shale and the Sylamore sandstone of Missouri; the Genundewa limestone of New York, the Silica and Olentangy shales of Ohio, the "Olentangy" shale of Ontario, the New Albany shale of Indiana, the Alpena limestone and Ferron Point formation of Michigan, and the clay above the Cedar Valley limestone in southern Minnesota. Occurs also in the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4078 (one specimen, figs. 5–7), 4079 (fig. 10), and 4080 (fig. 20).

ICRIODUS INCRASSATUS
Youngquist and Peterson, n. sp.
Plate 37, figures 1, 2, 25

The plate is thick, stout, and slightly recurved in long axis at and near the anterior end. The denticles of each lateral row number about four or five, and they are large and irregular in shape. The median row of denticles is not pronounced and does not persist beyond the posterior half of the plate. At the posterior end of this median row there is a very large, blunt denticle. An aboral groove is present, which is narrow anteriorly and which expands gradually toward the posterior end of the specimen where the groove is very deep.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Syntypes.—State Univ. Iowa, 4081 (one specimen, figs. 1, 2) and 4082 (fig. 25).

ICRIODUS IOWAENSIS
Youngquist and Peterson, n. sp.
Plate 37, figures 22–24, 27–29

This is an exceptionally large, stout form possessing denticles which are discrete but ridgelike. The long axis of these individuals is slightly curved laterally. The denticles are arranged in three longitudinal rows. The lateral rows consist of six or seven large denticles, which are roughly paired transversely. Denticles in the median row usually are not so large as those of the lateral rows, and they number about four or five. However, a single large denticle is present at one extremity, where it forms the posterior end of the specimen as well as the end of the median denticle row. All the denticles are discrete, those of the anterior portion of the conodont being most pronouncedly so. Aborally, the specimen is deeply grooved—narrowly so in the anterior end, broadly in the posterior portion. The specimens illustrated are paired individuals.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Syntypes.—State Univ. Iowa, 4083 (one specimen, figs. 22–24) and 4084 (one specimen, figs. 27–29).

ICRIODUS LANCEOLATUS
Youngquist and Peterson, n. sp.
Plate 37, figures 16, 17

The long axis of the specimen is straight, and the oral surface of the platform tapers narrowly, being lance-shaped in plan view. About seven discrete denticles are present in each of the lateral rows. About five denticles are present in the median row—the denticles of all three rows are aligned transversely. The posterior extension of the median row consists of three large denticles, the largest being the most anterior. This "crest" of three denticles inclines backwards at a considerable angle and is a characteristic which distinguishes this species from *I. expansus* Branson and Mehl, a closely related form. Aborally, the specimen is

narrowly grooved anteriorly, more broadly grooved posteriorly.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. of Iowa, 4085.

Icriodus parvus
Youngquist and Peterson, n. sp.
Plate 37, figures 11, 12

This small slender form has lateral rows of denticles but no distinct median row. The long axis of each specimen is slightly bowed. The inner oral side of the plate bears three regularly spaced discrete denticles. The outer side has about five denticles, the posterior two of which form the posterior end of the specimen. The anterior denticle forms the anterior extremity of the specimen. The posteriormost denticle is much larger than the others and inclines backwards. Aborally, there is a narrow groove, which expands at a uniform rate progressively posterior. There are no pronouncedly flared aboral margins.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Syntypes.—State Univ. Iowa, 4086 (fig. 11) and 4087 (fig. 12)

Icriodus rectus
Youngquist and Peterson, n. sp.
Plate 37, figures 3, 4, 13, 14, 26

The long axis of the specimen is straight in representatives of this species. The denticulation consists of lateral rows and a short median row of denticles. This median row does not persist to the anterior third of the platform, being supplanted there by the converging lateral rows of denticles. There are about four or five denticles in the median row including the large posteriormost one. The lateral rows also contain four or five denticles, all of which are considerably larger than most of those in the median row. Aborally, the conodont is very narrowly grooved in the anterior portion; the aboral margins of the posterior region are somewhat flared to enclose a deep suboval excavation.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Syntypes.—State Univ. Iowa, 4088 (one specimen, figs. 3, 4), 4089 (one specimen, figs. 13, 14) and 4090 (fig. 26).

Icriodus spicatus
Youngquist and Peterson, n. sp.
Plate 37, figures 8, 9

There are three longitudinal rows of denticles; the lateral rows each contain four denticles, the median row consists of about six denticles. The large, posteriormost denticle of the median row also makes up the posterior end of the specimen. The penultimate anterior denticle of the median row is considerably higher than any other denticle, and it gives the anterior portion of the specimen a spikelike appearance. Unlike the posterior denticle, this spike-like anterior denticle does not make up the end of the specimen, for a small denticle is present at the extremity of the platform. Aborally, the

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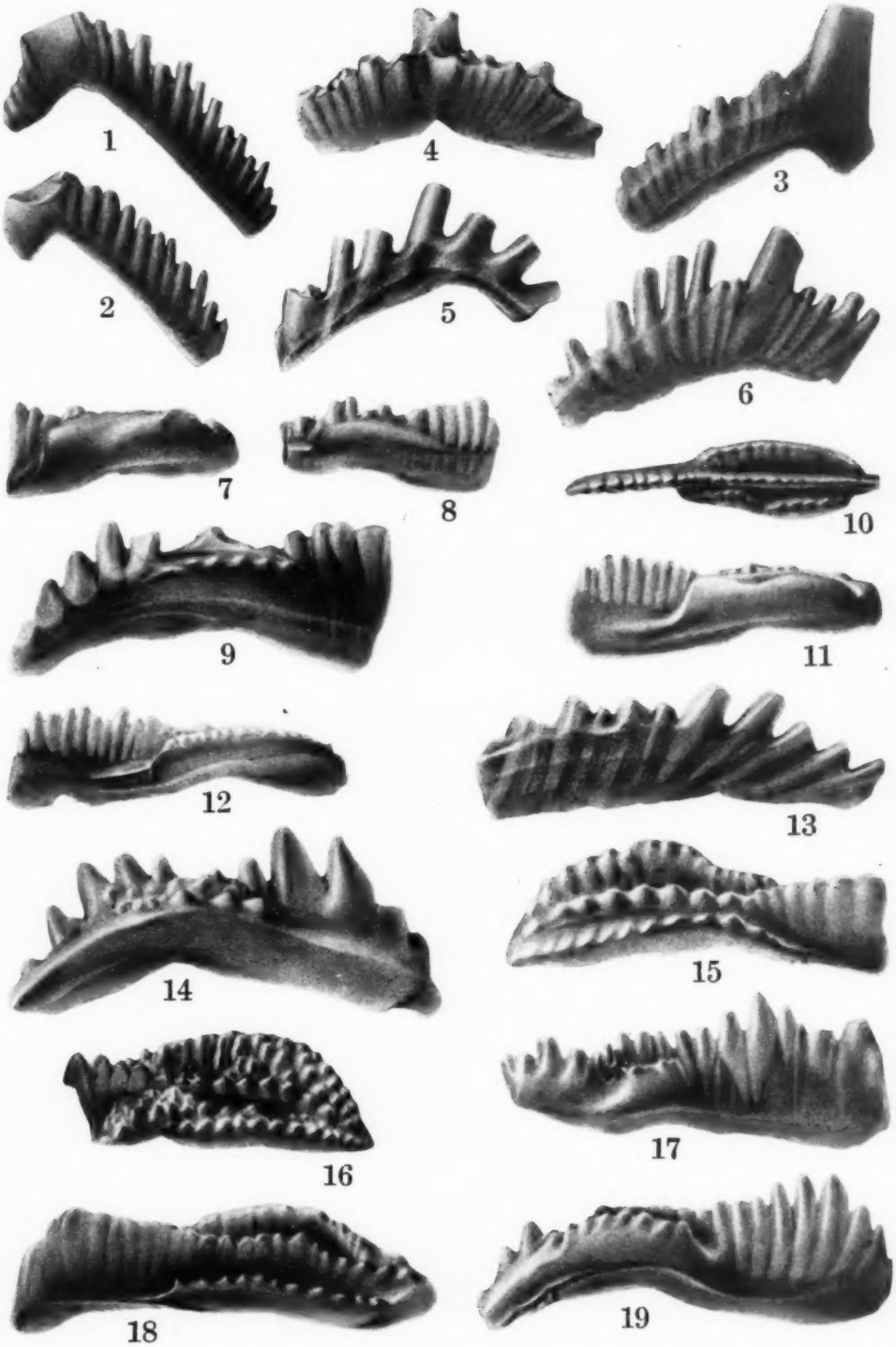
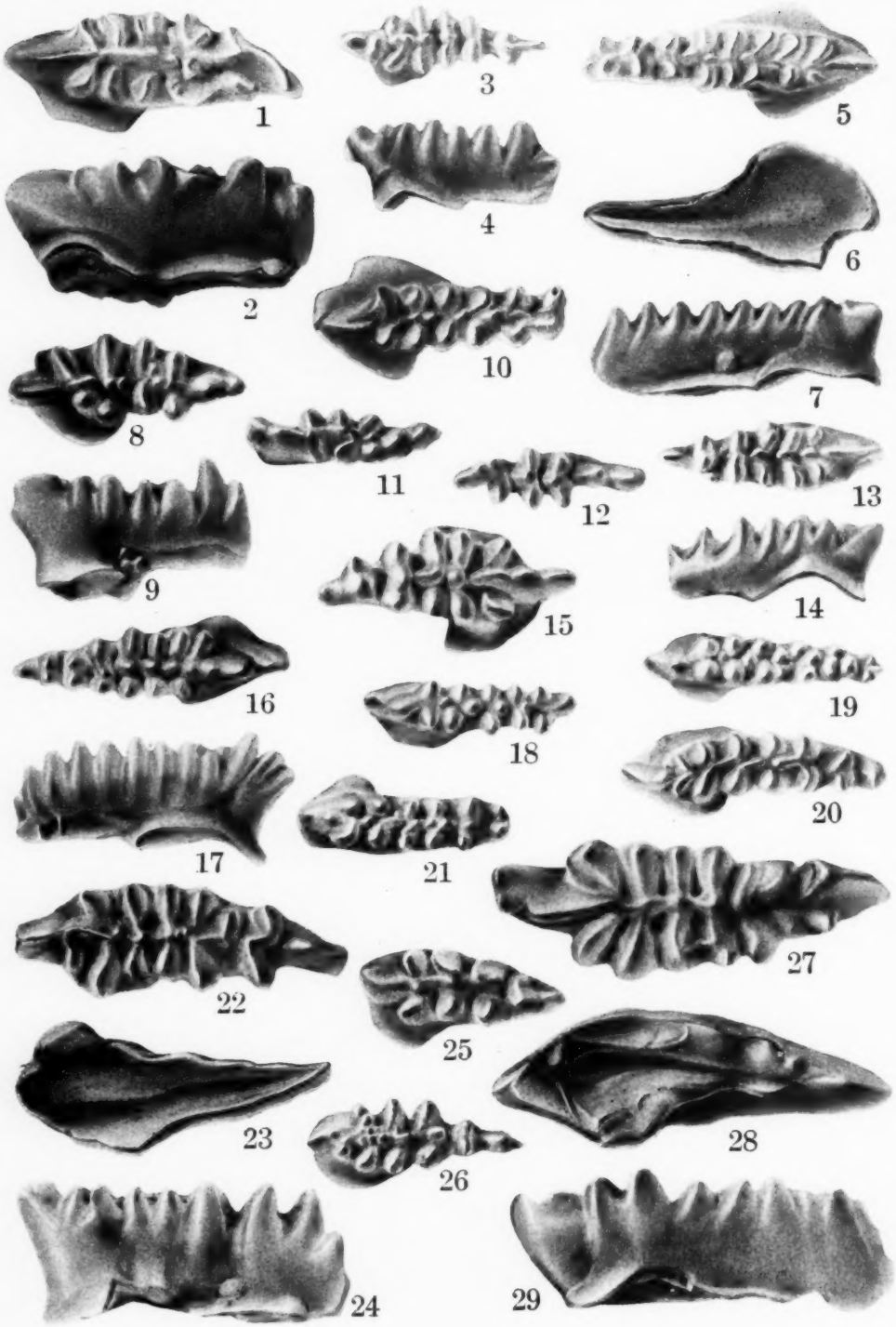
Explanation of Plate 36

All specimens are from the Sheffield formation exposed in the shale quarry near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa. All figures are ×40.

Figs. *1–3—Prioniodus bellulus* Youngquist. (p. 253)
4—Diplodella sp. (p. 244)
5—Angulodus? sp. (p. 244)
6—Angulodus compressus Youngquist and Peterson, n. sp. (p. 244)
7–9—Polygnathus brevilamina Branson and Mehl. (p. 249)
10–12—Polygnathus decorosa Stauffer. Figs. *10, 11* illustrate one specimen. (p. 250)
13—Hindeodella sp. (p. 246)
14—Polygnathus brevicornis Youngquist and Peterson, n. sp. (p. 249)
15—Polygnathus sheffieldensis Youngquist and Peterson, n. sp. (p. 251)
16—Polygnathus sp. (p. 252)
17—Polygnathus iowaensis Youngquist and Peterson, n. sp. (p. 250)
18—Polygnathus carinifera Youngquist and Peterson, n. sp. (p. 250)
19—Polygnathus postbrevicornis Youngquist and Peterson, n. sp. (p. 251)



Youngquist and Peterson, Sheffield Conodonts



Youngquist and Peterson, Sheffield Conodonts

anterior two-thirds of the specimen is deeply but narrowly grooved. The posterior third flares laterally to encompass a subcircular excavation. The long axis of the specimen is straight or only slightly curved laterally.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4091.

POLYGNATHUS BREVICORNIS
Youngquist and Peterson, n. sp.
Plate 36, figure 14

This is apparently a primitive polygnathid conodont in which neither the blade nor the platform is well developed. The holotype is moderately up-arched, sharply keeled aborally at and near the anterior and posterior extremities, and has a shallow anterior-posterior elongated escutcheon. This escutcheon lies directly beneath the region of the platform and is approximately two-thirds as long as the platform. Except for the area of this small platform, the oral surface of the conodont is entirely occupied by short, stout denticles, which are markedly expanded at their bases. The denticles are of the same amber-colored material as the base with which they merge, and at the anterior and posterior oral extremities the denticles appear merely as nodelike extensions of the base. The whole specimen is slightly bowed outward and the outer (figured) side exhibits a platform very much larger than that of the inner side. In addition, this outer platform is crenulated on its oral margin, whereas the smaller inner platform is smooth.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4092.

POLYGNATHUS BREVILAMINA
Branson and Mehl
Plate 36, figures 7–9

Polygnathus brevilamina BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 3, p. 246, pl. 21, figs. 3–6.

Polygnathus brevilamina Branson and Mehl. BRANSON and MEHL, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, p. 163.

We are referring three well-preserved specimens to this species. Our largest specimen (pl. 36, fig. 9) shows that anteriorly the blade is composed of denticles which are nearly or entirely sheathed by bar material. However, these denticles when viewed with transmitted light are seen to retain their individuality well down into the blade. The blade extends posteriorly as a carina, but this carina at the region of the small plat-

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EXPLANATION OF PLATE 37

All specimens are from the Sheffield formation exposed in the shale quarry near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa. All figures are ×40.

FIGS. *1, 2*—*Icriodus incrassatus* Youngquist and Peterson, n. sp. Two views of a single specimen. See also fig. *25*. (p. 247)
3, 4—*Icriodus rectus* Youngquist and Peterson, n. sp. Two views of a single specimen. See also figs. *13, 14, 26*. (p. 248)
5–7—*Icriodus expansus* Branson and Mehl. Three views of a single specimen. See also figs. *10, 20*. (p. 246)
8, 9—*Icriodus spicatus* Youngquist and Peterson, n. sp. Two views of a single specimen. (p. 248)
10—*Icriodus expansus* Branson and Mehl. See also figs. *5–7, 20*. (p. 246)
11, 12—*Icriodus parvus* Youngquist and Peterson, n. sp. (p. 248)
13, 14—*Icriodus rectus* Youngquist and Peterson, n. sp. Two views of a single specimen. See also figs. *3, 4, 26*. (p. 248)
15—*Icriodus circularis* Youngquist and Peterson, n. sp. (p. 246)
16, 17—*Icriodus lanceolatus* Youngquist and Peterson, n. sp. Two views of a single specimen. (p. 247)
18, 19—*Icriodus alternatus* Branson and Mehl. See also fig. *21*. (p. 246)
20—*Icriodus expansus* Branson and Mehl. See also figs. *5–7, 10*. (p. 246)
21—*Icriodus alternatus* Branson and Mehl. See also figs. *18, 19*. (p. 246)
22–24—*Icriodus iowaensis* Youngquist and Peterson, n. sp Three views of a single specimen. See also figs. *27–29*. (p. 247)
25—*Icriodus incrassatus* Youngquist and Peterson, n. sp. See also figs. *1, 2*. (p. 247)
26—*Icriodus rectus* Youngquist and Peterson, n. sp. See also figs. *3, 4, 13, 14*. (p. 248)
27–29—*Icriodus iowaensis* Youngquist and Peterson, n. sp. Three views of a single specimen. See also figs. *22–24*. (p. 247)

form becomes denticulate and this denticulation continues to the posterior end of the specimen. The denticles in the posterior region are rather large, essentially round in cross section, and greatly expanded at their bases to encompass the whole of the oral surface of the specimen. The platform is short and not particularly wide. Aborally the specimen is keeled principally at the extremities. Comparison of figures 7 and 8 with figure 9 illustrates the size range of this species in our Sheffield collection.

Occurrence.—Grassy Creek shale of Missouri, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4093 (fig. 7), 4094 (fig. 8), 4095 (fig. 9).

POLYGNATHUS CARINIFERA
Youngquist and Peterson, n. sp.
Plate 36, figure 18

The specimen in long axis is both uparched and bowed to a moderate degree. The blade reaches its maximum height about three denticles back of its anterior end. It is composed of about 10 laterally compressed, completely sheathed denticles, which grade into the material of the lower portion of the blade. A very prominent orally-crenulated carina extends the length of the plate from the point where it joins the blade. The median-lateral oral areas of the plate are deeply grooved—the margins of the plate are strongly curved upward. Except for the presence of a very small flattened zone beneath the anterior end of the plate, the entire aboral margin of the specimen tapers to form a sharp keel.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4096.

POLYGNATHUS DECOROSA
Stauffer
Plate 36, figures 10–12

Polygnathus decorosus STAUFFER, 1938, Jour. Paleontology, vol. 12, pp. 413, 438, pl. 53, figs. 1, 5, 6, 10, 11, 15, 16, 20, 30.
Polygnathus decorosa Stauffer. YOUNGQUIST, 1947, Jour. Paleontology, vol. 21, p. 109, pl. 24, fig. 21.

The plate is gently arched, and the entire specimen is very slightly bowed. The blade contains 10 to 12 denticles. which are sheathed nearly to their apices but in transmitted light are seen to retain their individuality to a point about midway aborally in the blade. The under surface of the blade is moderately keeled except in the extreme posterior portion, where a small groove widens to form an escutcheon beneath the anterior end of the plate. Posterior of the escutcheon the keel continues to the extremity of the plate in a subdued form.

Occurrence.—The Olentangy shale of Ohio, the "Olentangy" shale of Ontario, and an unnamed Upper Devonian shale 1½ miles northeast of North Liberty, Iowa. Also occurs in the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4097 (one specimen, figs. 10, 11) and 4098 (fig. 12).

POLYGNATHUS IOWAENSIS
Youngquist and Peterson, n. sp.
Plate 36, figure 17

The blade of representatives of this species is by far the most prominent element of the specimen. The denticles of the blade are irregular in size, shape, and manner of insertion, but all are discrete at their apices. Only a very small slightly nodose lateral expansion about midlength of the blade provides the platform which places this form in *Polygnathus*. Since the platform is so small, no carina can be said to be present, for the blade structure clearly persists the entire length of the specimen. In the region of the plate and posterior of it, the denticles of the blade are more rounded and somewhat smaller than those of the anterior part of the blade. Aborally, the entire specimen is keeled and, except for a small flattening of the keel in the area below the platform, no trace of an escutcheon is present. The blade anterior to the plate is straight, in the vicinity of the plate it is flexed laterally outward, and posterior of the plate the blade is curved slightly inward. The aboral outline of the entire specimen presents a convex rather than a concave appearance—this is accomplished principally by the oral curvature of the posterior end. The outer lateral view of the holotype is shown.

This form appears to represent a very

early stage of polygnathid development. It resembles *P. brevilamina* Branson and Mehl and *P. angustidisca* Youngquist in the shortness of the platform, but differs from both in having a convex aboral profile and in the lateral flexures of the blade.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4099.

POLYGNATHUS PAPILLATA Youngquist and Peterson, n. sp.
Plate 38, figure 12

The oral surface of this platelike form is almost entirely nodose rather than rugose. A carina is present anteriorly where it joins a small blade. Posteriorly, however, the carina does not persist beyond the midpoint of the plate. The entire specimen is suboval in outline, strongly up-arched, but not appreciably curved laterally. The aboral surface is gently convex downward. The keel is not particularly well developed and a very small escutcheon or "zone of attachment" is evident. When properly lighted, fine concentric growth lines are readily distinguished. The figured specimen preserves only the posterior portion of the blade.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4100.

POLYGNATHUS POSTBREVICORNIS Youngquist and Peterson, n. sp.
Plate 36, figure 19

The platform of representatives of this species is very narrow and is up-arched; the entire specimen is strongly bowed. There is a small keel on the aboral surface of the blade but none beneath the platform, though at the extreme posterior end of the specimen a small aboral ridge is evident. There is no aboral excavation. The denticles of the blade number about eight, and they are oval in cross section and only partially sheathed. The carina extending posteriorly from the blade is strongly nodose across the platform and becomes denticulate at and near the posterior end of the specimen. This species is close to *P. brevicornis*, n. sp., and *P. brevilamina* Branson and Mehl but appears to be further advanced in that the platform as well as the blade are somewhat better developed.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4101.

POLYGNATHUS RETRORSA Youngquist and Peterson, n. sp.
Plate 38, figure 11

This species is particularly characterized by the sharp lateral recurving of the extreme posterior portion of the plate. The plate is strongly up-arched and its oral surface bears a carina, which is also sharply recurved at its posterior extremity. Anteriorly, the carina merges with a short, stout triangular-shaped blade, which does not extend appreciably beyond the plate. The remainder of the oral surface of the plate is chiefly rugose with a small nodose area near the carina. Aborally, the plate is broadly V-shaped; a distinct longitudinal keel is most pronounced at the extremities of the plate but persists throughout. The midportion of the keel is flattened somewhat, but there is no excavation or prominent escutcheon evident.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4102.

POLYGNATHUS SHEFFIELDENSIS Youngquist and Peterson, n. sp.
Plate 36, figure 15

The entire specimen is slightly bowed as well as moderately up-arched. The aboral surface of the plate is V-shaped, sharpening to a keel, which also extends anteriorly beneath the blade. A very small escutcheon is present near the anterior end of the plate. The plate is thick and the oral margins are crenulated. The blade is composed of about five confluent, laterally compressed denticles which are almost entirely sheathed. The carina is strongly nodose; it extends from near the posterior end of the plate to the blade. The plate is unequally divided by the carina—the outer side of the plate being somewhat flared laterally. The figured specimen is illustrated from the inner side by an oblique view. This form is reminiscent of *P.*

triangularis Branson and Mehl from the Grassy Creek shale of Missouri, but differs in the fact that the plate flares laterally on the outer side, tapers at both the extremities and thus does not have a "subtriangular" outline.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Holotype.—State Univ. Iowa, 4103.

POLYGNATHUS VARINODOSA Branson and Mehl
Plate 38, figure 10

Polygnathus varinodosa BRANSON and MEHL, 1934 [1933], Missouri Univ. Studies, vol. 8, no. 3, p. 249, pl. 20, fig. 15, pl. 21, figs. 9, 11, 12, 18.

Polygnathus varinodosa Branson and Mehl. BRANSON and MEHL, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, p. 166.

Polygnathus varinodosa Branson and Mehl. BRANSON, 1944, Missouri Univ. Studies, vol. 19, no. 3, p. 173.

The plate is thick, elongated, and moderately up-arched. The oral surface carries a median carina, which extends the length of the plate and resolves into a small blade anteriorly. The remainder of the oral plate surface is strongly rugose. Aborally, the plate is V-shaped, for it has a very pronounced median keel. This keel persists the length of the plate but becomes somewhat flattened in the midportion of the plate, though no escutcheon is present. The figured specimen is incomplete in that the blade at the anterior end of the plate is broken away.

Occurrence.—Grassy Creek shale and Louisiana limestone of Missouri, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotype.—State Univ. Iowa, 4104.

POLYGNATHUS VERRUCOSA Youngquist and Peterson, n. sp.
Plate 38, figure 13

Ancyrognathus n. sp. MEHL and QUIGLEY, and QUIGLEY, respectively, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, pp. 153, 158, pl. 26, fig. 40.

Polygnathus sp. MEHL and QUIGLEY, and QUIGLEY, respectively, 1944, *in* BRANSON, Missouri Univ. Studies, vol. 19, no. 3, pp. 153, 158, pl. 26, fig. 45.

This exceptionally thick, oval plate is gently up-arched. A carina is present on the oral surface but is not pronounced. The central portion of the plate is strongly rugose whereas the periphery is somewhat nodose. The posterior extremity of the figured specimen is missing, but, as in closely related forms such as *P. retrorsa*, n. sp., it probably consisted of a short, stout blade. Unlike the other polygnathids in our collection, this species is decidedly concave on its aboral surface. This concavity is divided into two subequal parts by a median keel which persists the length of the plate but is not large. Fine concentric growth lines are also present on the aboral surface.

Occurrence.—Sylamore sandstone of Missouri, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Repository.—State Univ. Iowa, 4105.

POLYGNATHUS sp.
Plate 36, figure 16

The plate is suboval in outline though somewhat pointed posteriorly and the entire specimen is bowed slightly as well as up-arched. Aborally, the plate is broadly V-shaped. A small keel is interrupted by a shallow escutcheon at the anterior end of the plate. The oral plate surface is nodose and a

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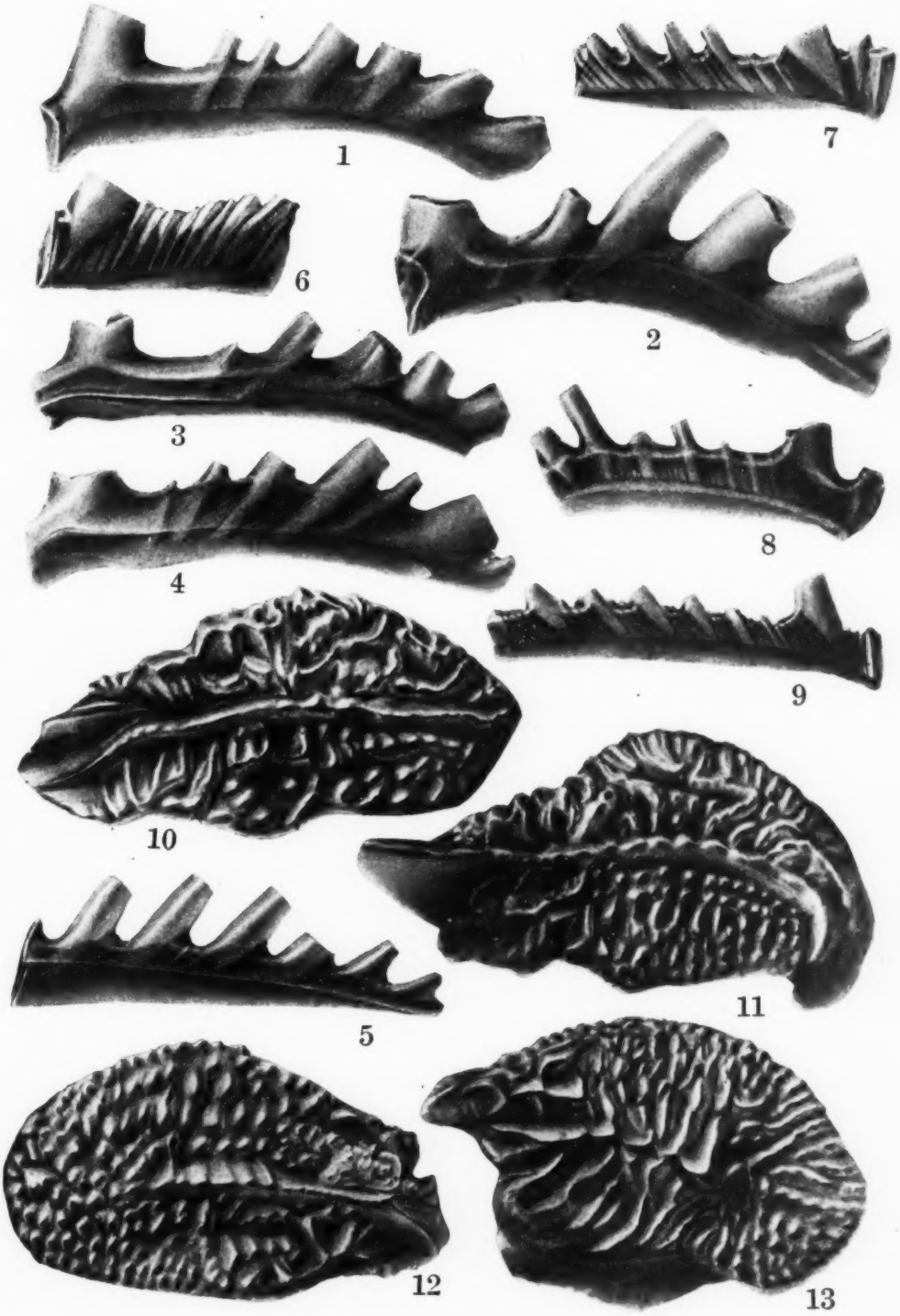
EXPLANATION OF PLATE 38

All specimens are from the Sheffield formation exposed in the shale quarry near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa. All figures are ×40.

FIGS. *1–5*—*Hindeodella millerella* Youngquist and Peterson, n. sp. (p. 245)
6—*Hindeodella lambtonensis* Stauffer. (p. 245)
7, 8—*Hindeodella acuta* Branson and Mehl. (p. 245)
9—*Hindeodella aculeata* Huddle. (p. 244)
10—*Polygnathus varinodosa* Branson and Mehl. (p. 252)
11—*Polygnathus retrorsa* Youngquist and Peterson, n. sp. (p. 251)
12—*Polygnathus papillata* Youngquist and Peterson, n. sp. (p. 251)
13—*Polygnathus verrucosa* Youngquist and Peterson, n. sp. (p. 252)



Youngquist and Peterson, Sheffield Conodonts

UNIV. OF MICH.

small median carina persists from the blade to the posterior end of the plate. The blade is incomplete on the figured specimen, but presumably it was composed of four or five laterally compressed, partially sheathed denticles.

Occurrence.—Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Repository.—State Univ. Iowa, 4106.

PRIONIODUS BELLULUS Youngquist
Plate 36, figures 1–3

Prioniodus bellulus YOUNGQUIST, 1945, Jour. Paleontology, vol. 19, p. 365, pl. 55, fig. 4.

The holotype of this species has been available to us for direct comparison. Study of this form, which was originally described from shales near Middle Amana, Iowa, leaves little doubt but that conspecific conodonts occur also in the Sheffield formation. The specimen illustrated by figure 1 on plate 36 is the best preserved of the three individuals we are referring to this species. The posterior bar extension carries 13 rounded denticles which are deeply "inserted." The anticusp is deflected outward, and is crenulated orally by four slightly erupted "germ" denticles. Both the bar and anticusp are sharply keeled aborally. The anticusp is fractured close to the cusp on figure 2, and on figure 3 both the posterior bar extension and the anticusp are somewhat incomplete.

Occurrence.—Upper Devonian shale 0.4 mile west of Middle Amana, Iowa, and the Sheffield formation near the center of sec. 9, T. 93 N., R. 20 W., Franklin County, Iowa.

Hypotypes.—State Univ. Iowa, 4107 (fig. 1), 4108 (fig. 2), 4109 (fig. 3).

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EOCENE FORAMINIFERA FROM HAHA-JIMA (HILLSBOROUGH ISLAND)

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ABSTRACT—Haha-jima is entirely formed of Eocene rocks. The uppermost horizon of the Eocene series is hard limestone with *Biplanispira* and is assigned to the Priabonian in age. The underlying friable rocks, mostly tuffaceous or agglomeratic, yield well-preserved Eocene Foraminifera such as *Nummulites boninensis* n. sp. All these species are referred to the Lutetian; *Nummulites boninensis* is restricted to the lower half, whereas *Discocyclina* (*Aktinocyclina*) *colcanapi* predominates in the upper half, and *Alveolina javanus* var. and *Eorupertia boninensis* persist throughout the Lutetian beds. *Nummulites boninensis* closely resembles *N. gizehensis* (Forskål) except in the pattern of the meandriform septal filaments. Moreover, in *N. gizehensis* the whorls are dilated toward the proloculus and irregular, while those of *N. boninensis* are closely and regularly coiled throughout. Pillars embedded in the spiral lamellae are much better developed in the latter than in the former species.

INTRODUCTION

T. WAKIMIZU (Yabe, 1911) first recognized the presence of Eocene beds in Haha-jima (Hillsborough Island) of the Ogasawara (Bonin) group, by finding nummulites on that island about half a century ago. Tokunaga (1902), encouraged by this discovery, soon afterward undertook geologic reconnaissance work in the island group and published an important paper on its geology and paleontology. In 1911, Yabe recorded the occurrence of "*Orthophragmina*" cf. *O. colcanapi* Douvillé in the collections of Yamazaki and Oinouye from Nishi-ura, Haha-jima. Later, Yabe (1921) and Yabe and Hanzawa (1920) described some Eocene Foraminifera, such as *Sagenina regularis* (Douvillé), *Sagenina expansa* Yabe, *Placopsilina cenomana* d'Orbigny, *Lituotuba ? eocenica* Yabe, and *Eorupertia boninensis* (Yabe and Hanzawa) in the collection from Shizukazawa, Oki-mura, Haha-jima, made by T. Matsuo while carrying out a petrological study of the volcanic rocks of the island group.

In 1925 I made a geological trip to Chichi-jima (Peel Island), Haha-jima (Hillsborough Island), and Naka-Iwo-Jima (Sulphur Island), and collected numerous well-preserved Eocene Foraminifera from Haha-jima, besides some Oligocene Foraminifera, *Lepidocyclina* (*Eulepidina*) sp., *Austrotrillina howchini* (Schlumberger), and *Heterostegina* sp. from the south promontory (Minami-zaki) of Chichi-jima. Most of the Lutetian Foraminifera occur in friable tuffs and are easily extracted from the matrix.

STRATIGRAPHY OF HAHA-JIMA (HILLSBOROUGH ISLAND)

It is difficult to ascertain the stratigraphic succession of the Eocene foraminiferal rocks in Haha-jima because this island is cut by meridional and transverse faults. On tracing these rocks from south to north the following fossil localities were found.

Along the sea cliff of Nanking Beach a white tuff, seven meters thick, rests unconformably on andesite which is considered to be the basement of the island. This tuff is in turn conformably covered by two *Nummulites*-bearing beds. The lower *Nummulites* bed is buff-colored, 16 meters thick, and contains abundant *Nummulites boninensis* and *Alveolina javanus* var. It is separated from the upper *Nummulites* horizon by white tuff seven meters thick. The upper *Nummulites* bed is also buff-colored, 20 meters thick, and rich in *Nummulites boninensis*, *Discocyclina* (*Aktinocyclina*) *colcanapi*, *Alveolina javanus* var., and *Eorupertia boninensis*. These beds dip toward the southwest at an angle of about 20°; only the upper *Nummulites* bed is exposed as far north as Cocoanut Beach along the sea cliff, the lower beds plunging below sea level.

The same *Nummulites* bed as that at Nanking Beach is exposed at the road cut of Yumemizaka, Hyogidaira, between Cocoanut Beach and Oki-mura, the principal village of the island.

Limestone and tuff lie horizontally along the sea cliff of Onion Beach, the east side of the small embayment of Oki-mura. The upper part of the cliff consists of a massive, white, compact and cavernous limestone 18 meters thick, containing *Biplanispira absurda* Umbgrove (formerly assigned to *Pellatispira*). The lower part of the sea cliff is an alternation of thin reddish-brown and greenish-gray *Globigerina* tuffs with a peculiar type of *Discocyclina* (*Asterocyclina*), the thickness being three meters.

Northeast of Oki-mura, at the entrance of Rosu-dani, a northeast-southwest valley, a white massive *Globigerina* limestone crops out. This limestone sparingly contains *Nummulites boninensis* (megalospheric form only) and *Alveolina javanus* var., besides shark teeth and other fish remains. It is known as Rosu-ishi and is quarried for building stone and other purposes. It dips toward the southwest at an angle of 50°. It is supposed to plunge under the *Globigerina* tuffs of Onion Beach and is estimated to be more than 20 meters thick.

Other exposures of *Nummulites*-bearing tuffs and agglomerates are found along the upper course of the Rosu-dani, 80 meters above sea level, and Funaki-yama, east of Kenzaki-yama; the former dips toward the south-southwest at an angle of 10°, and the latter toward the northwest at an angle of 40°.

At Shizukazawa, 300 meters east of the village of Oki-mura, a buff tuff full of *Nummulites boninensis, Alveolina javanus* var. and *Eorupertia boninensis*, with a southwest dip of 10°, is exposed along the bottom of a creek for a distance of 400 meters, under a dark green tuff.

Near the bridges of Nino-hashi and Sanno-hashi north of Oki-mura, the same *Nummulites* bed as that of Shizukazawa crops out on the road.

The south promontory of the small Nishi-ura embayment and Akaiwa, a rock lying in the sea just west of the promontory, consist of three horizontal beds. The lowest horizon is light buff-colored calcareous tuff 15 meters thick, containing *Eorupertia boninensis* and *Alveolina javanus* var. The middle bed, the same color as the preceding, 25 meters thick, contains *Discocyclina* (*Aktinocyclina*) *colcanapi*. The upper bed, found only on the summit of Akaiwa, is a pink or white indurated limestone 10 meters thick with abundant remains of *Discocyclina* (s. l.) and pelagic and bottom-dwelling smaller Foraminifera. The lower *Eorupertia* tuff is also found on the road 100 meters north of Nishi-ura-bashi.

On the top of Nenbutsu Pass, 200 meters above sea level, buff-colored tuffaceous limestone with *Nummulites boninensis* and *Eorupertia boninensis* covers white tuff, both dipping east-northeast at an angle of 20°.

Another exposure of *Nummulites*-bearing tuff is found in the road between Sakai-dake and Sekimon-yama.

A very extensive exposure of the *Biplanispira* limestone like that seen at Onion Beach near Oki-mura, 100 meters thick, rests conformably on an alternation of andesitic agglomerates and tuffs, at Sekimon-yama.

From these field observations I have compiled the following composite section of the Eocene beds of Haha-jima, the total thickness being estimated at about 200 meters. The composite section, in descending order, is as follows.

		Meters
11	*Biplanispira* limestone: white, compact and cavernous, containing *Biplanispira absurda* (Umbgrove), *Pellatispira* sp., *Acervulina* n. sp. Sekimon-yama and Onion Beach	100
10	*Discocyclina* limestone: pink or white, indurated, with abundant *Discocyclina* (s. l.) and pelagic and benthonic Foraminifera. The top of Akaiwa, Nishi-ura	10
9	*Globigerina* tuff: reddish-brown and greenish-gray, abundant pelagic and benthonic Foraminifera, and *Discocyclina* (s. l.). Onion Beach, Oki-mura	3–5
8	*Discocyclina-Alveolina* tuff: buff-colored, with abundant *Discocyclina* (*Aktinocyclina*) *colcanapi* and *Alveolina javanus* var. Nishi-ura	25
7	*Eorupertia-Alveolina* tuff: buff-colored, with abundant *Eorupertia boninensis, Alveolina javanus* var., *Lithothamnium*, corals, echinoids and mollusks. Nishi-ura and 100 meters north of Nishi-ura-bashi	15
6	Tuff: dark green, Shizukazawa . . . several meters	?
5	*Nummulites-Discocyclina* tuff and agglomerate: buff-colored, with *Nummulites boninensis* and *Discocyclina* (*Aktinocyclina*) *colcanapi*. Cocoanut Beach, Nanking Beach	20
4	Tuff: white	7
3	*Nummulites* tuff: Buff-colored, with abundant *Nummulites boninensis, Alveo-*	

lina javanus var., and *Eorupertia boninensis*. Nanking Beach, Cocoanut Beach, Shizukazawa, Yumemizaka, Rosu-dani, Funaki-yama, Nenbutsu Pass, Sakaidake..... 16
(Rosu-ishi, the *Globigerina* limestone may be referred to a deeper facies of this tuff, which has been suggested as a shallow-water deposit of less than 200 meter depth, in Yabe's study of some arenaceous Foraminifera encrusting the surface of *Nummulites* tests.)
2 Tuff: white..... 7
1 Andesite basement rock

The Eocene beds are locally intercalated with some andesite lava in several horizons, except the uppermost *Biplanispira*-limestone which is destitute of pyroclastic material. This fact suggests that the volcanic activity that took place in the Lutetian age, during which the *Nummulites*-bearing beds were deposited, ceased before the Priabonian age, in which the *Biplanispira*-limestone was formed.

As mentioned below, the *Biplanispira*-limestone appears to be conformable with the alternation of andesitic tuffs and agglomerates at Sekimon-yama, while it rests conformably on the *Globigerina*-rocks at Onion Beach. And also its pure limestone nature is quite distinct from the underlying formation. The fact is likely to lead us to assume a disconformity between the Priabonian and the Lutetian formation. But I think there are strong changes of facies in the Lutetian beds, since these formations contain much pyroclastic material, and there is no disconformity between the Eocene foraminiferal rocks of Haha-jima.

DESCRIPTION OF SPECIES

NUMMULITIDAE Reuss, 1861

Genus NUMMULITES Lamarck, 1801

NUMMULITES BONINENSIS Hanzawa, n. sp.

Plates 39 and 40

Megalospheric form:

Test lenticular with a sharp periphery, sometimes asymmetrical, with one side more inflated than another; moderate in size, attaining 6.3 mm. in diameter, and 2 mm. in thickness, but usually 5 mm. across and 2 mm. thick; surface smooth, septal filaments numerous, radial, flush with the general surface of the test; heads of pillars embedded in spiral lamellae, usually found on septal filaments as tiny spots, sometimes elevated as granules on the surface of the test; consisting of a spherical proloculus, 775–1,170μ. in diameter and 3–5 whorls (3 whorls in the majority of specimens); first whorl divided by septa into 5–7 chambers (6 chambers most common), second, 11–16 chambers (usually 12 chambers), third, 16–30 chambers (usually 20–24).

Microspheric form:

Test discoidal, both lateral surfaces nearly parallel, more or less suddenly attenuated to a sharp periphery, sometimes undulated as a whole; very large in size, attaining more than 60 mm. in diameter and more than 10 mm. in thickness, but usually 40–50 mm. across and 8–10 mm. thick; surface smooth, marked with numerous meandriform septal filaments, complicately anastomosing, 3 fila-

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EXPLANATION OF PLATE 39

Nummulites boninensis Hanzawa, n. sp. Cotypes, Shizukazawa, Oki-wura, Haha-jima (Hillsborough Island), the Ogasawara (Bonin) group. (I.G.P.S. Coll. no. 20034).

FIGS. *1–7*—Lateral views of microspheric forms. Natural size. *2*, Granulated specimen (Twinned test). (p. 256)

8—Showing internal structure of a microspheric specimen, artificially split along the sagittal plane of the test. The splitting of the microspheric specimen along the sagittal plane was pretty easily made by heating the specimen on a hot plate and then instantaneously placing in cold water for sudden cooling. The sagittal plane of the test is weaker than the other part of the test in structure, because the marginal plexus of the canal system runs along the sagittal plane, which causes an easy cracking.

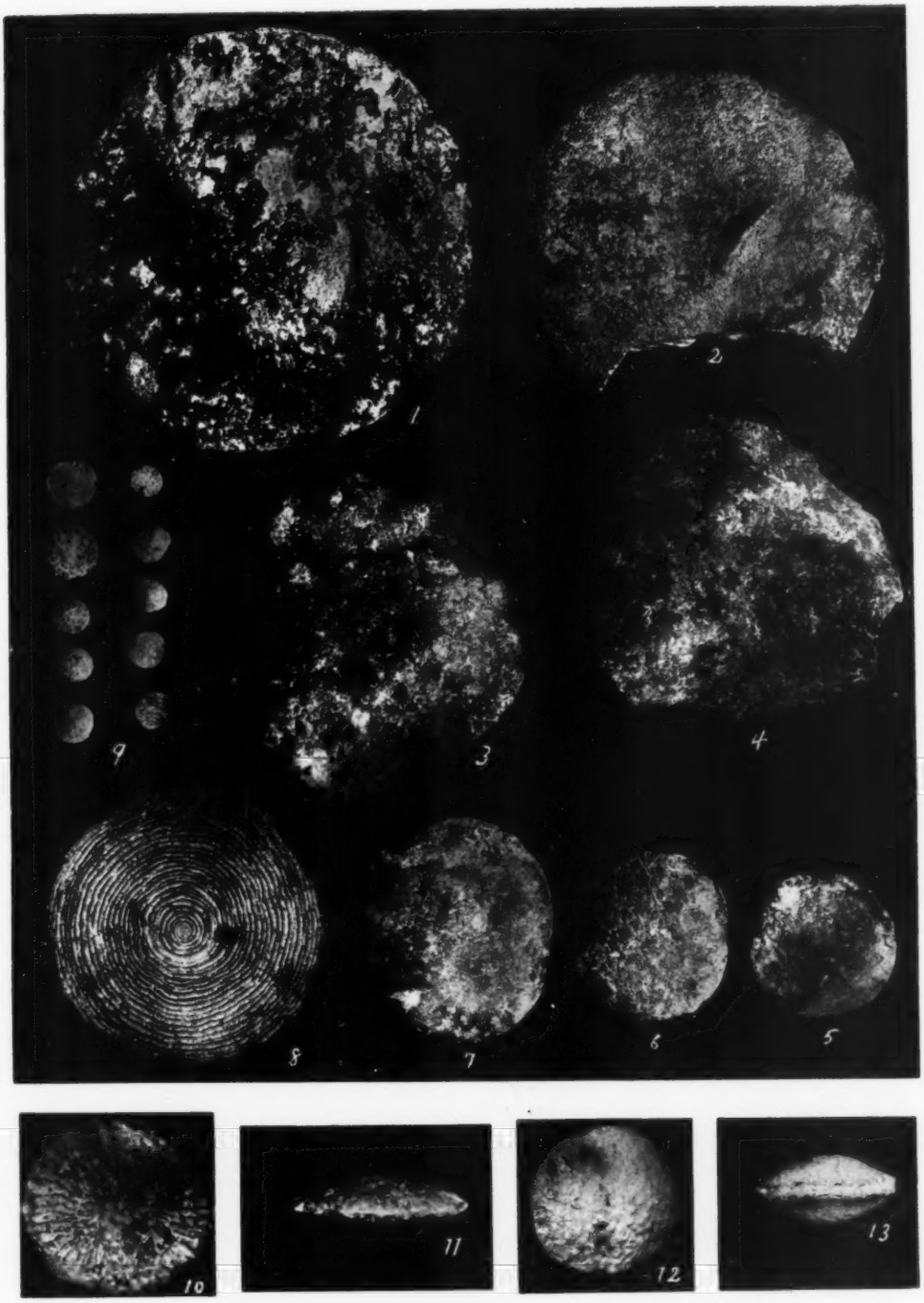
9—Lateral views of megalospheric forms. Natural size.

10—Lateral view of megalospheric form. ×5.

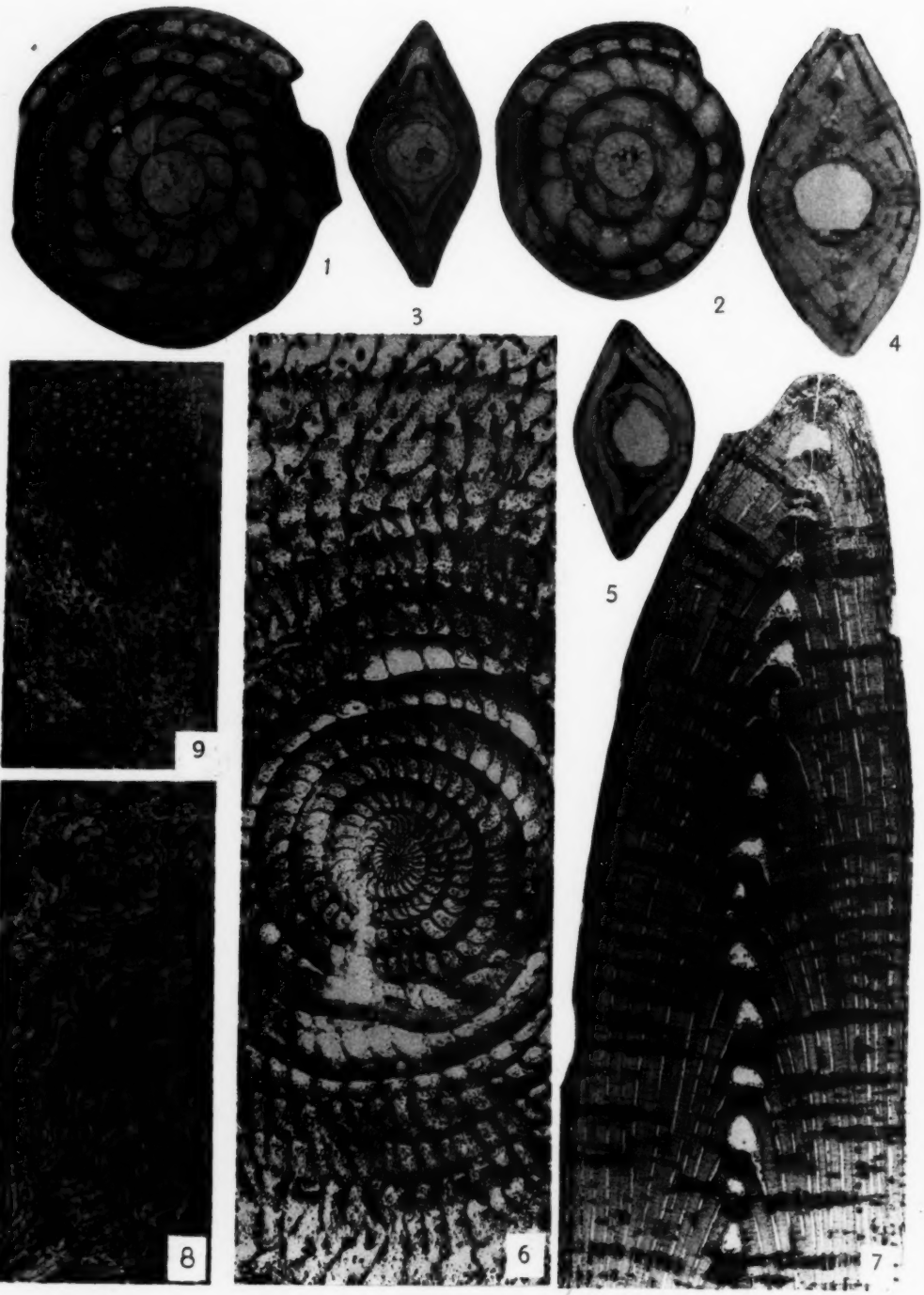
11—Peripheral view of the same specimen as fig. 10. ×5.

12—Lateral view of megalospheric form of granulated specimen. ×5.

13—Peripheral view of the same specimen as fig. 12. ×5.



Hanzawa, *Nummulites boninensis*



Hanzawa, *Nummulites boninensis*

ments being counted within 1 mm.; heads of pillars embedded in spiral lamellae, raised or not raised on the genéral surface of the test, found usually on the septal filaments, sometimes between two adjacent filaments; consisting of a minute proloculus and closely coiled whorls, more than 30 in number; whorls divided by septa into chambers, which are 160 in number in the 20th whorl.

As shown in plate 39, figs. 2, 12, 13 and plate 40, fig. 9, some specimens, both microspheric and megalospheric, display considerable granulation on the test. But the granulated specimens are hardly distinguishable from the comparatively smooth specimens by means of thin slices under the microscope. As we notice in plate 40, fig. 7 the vertical pillars started from the sagittal plane of the test sometimes attain the surface of the test or sometimes do not reach the surface of the test. The pillars are usually 218μ across in both the granulated and smooth specimens. As a rule the smooth specimens are buff-colored, while the granulated ones are white. The latter form is rarely found in the fossil assemblage of the *Nummulites* beds mentioned above.

By the statistics cited below, we know that the proloculus is 1,170–775μ in diameter, of which 775–870μ being most predominant, number of whorls is 3–5, of which 3–4 being most common, as to the number of chambers, 6 (exceptionally 5 or 7) in the first whorl, 12 (sometimes 11 or 13) in the second, 20–24 (25 or 26 exceptionally) in the third, 24–34 in the fourth; the height of whorls is ca. 2 mm. in the first, ca. 3 mm. in the second, ca. 4.4 mm. in the third, and ca. 5 mm. (6.3 mm. in maximum) in the fourth, and chambers are ca. 2 mm. in width in the last whorl.

The largest specimen of this species at my disposal attains 62 mm. in diameter and 12 mm. in thickness. Specimens 50 mm. across and 10 mm. thick to 40 mm. across and 8 mm. thick are most common in the population of Shizukazawa. The chambers increase the height very slowly in accordance with the growth of the test in the young stage, but the height of the chambers becomes nearly constant from the half way stage of growth, namely, the height is measured as 435μ as usual in the adult stage of growth of the test and also the thickness of the marginal cord is the same as the height of chambers in the later stage of growth of the test.

Remarks: The present form of Foraminifera was once recorded by S. Tokunaga as *Nummulites javanus* Verbeek. Recently H. W. Doornink assigned *Nummulites javanus* Verbeek to *Camerina perforata* (Montfort) (= *Camerina obtusa* Sowerby) and *Camerina gizehensis* (Forskål), the former of which is provided with a blunt periphery and the latter, with a sharp edge. He admitted a great variability of *Camerina javana* (Verbeek) and grouped up the varieties proposed by P. Rozloznik, and P. de la Harpe, as J. Boussac, J. Flandrin, J. Cuvillier, etc. had treated the species cited above.

Nummulites gizehensis (Forskål) has been described by several authors from Central and South Europe, North Africa, and Central Asia and assigned to the Lutetian.

The megalospheric specimens of the present form are very close to *Nummulites gizehensis* described by Doornink from Padosan, Java, as the latter possesses 6 chambers in the first whorl, 10 in the second, and consists of 3 whorls, while the former

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EXPLANATION OF PLATE 40

Nummulites boninensis Hanzawa, n. sp. Cotypes, Shizukazawa, Oki-mura, Haha-jima (Hillsborough Island), the Ogasawara (Bonin) group. All figures ten times natural size.

FIGS. *1, 2*—Sagittal sections of megalospheric form. (p. 256)
3, 4, 5—Axial sections of megalospheric form.
6—Sagittal section of microspheric form.
7—Axial section of microspheric form.
8—A part of lateral view of microspheric form showing pattern of septal filaments and pillars.
9—Similar view of a granulated microspheric specimen.

Statistics of *Nummulites boninensis Hanzawa*, n. sp. (megalospheric)

Specimens	a	b	c					d			
			I	II	III	IV	V	I	II	III	IV
1	775	3	6	12	19			1.78	3.14	3.82	
2	915	3½	7	12	24	6		1.92	3.00	3.82	
3	915	3½	5	12	20	7		1.57	3.14	3.70	4.70
4	775	5	6	13	23	34	43	1.74	2.84	3.90	4.35
5	775	4	5	14	30	43		1.26	2.53	3.78	5.00
								2.30	3.44	4.55	
6	960	4	6	16	24	30		2.08	3.20	3.95	
7	960	3	6	12	24			2.18	3.66	4.45	
8	870	3½	6	12	20	11		2.08	3.20	3.95	4.80
9	830	4	7	12	20	30		2.21	3.62	4.55	
10	1,170	3	6	15	26	8		1.91	3.04	4.50	4.90
11	1,000	4	7	13	21	34	13	2.00	3.04	3.99	4.80
12	870	5	6	12	20	27	22	1.91	3.08	4.00	
13	830	3	6	11	22			1.13	3.09	3.90	4.65
14	915	4½	7	13	25	26	14				
15	870	4	6	13	24	29	7	1.19	3.04	4.16	4.90
16	915	4½	6	13	20	24	13	1.82	3.04	4.20	5.10
17	1,171	3	6	11	16	5		2.13	3.65	4.35	
18	870	3	6	12	18			2.00	2.92		

N.B. a = diameter of proloculus in μ, b = number of whorls, c = number of chambers in whorls, d = height of whorls in mm., I = 1st whorl, II = 2nd, etc.

Statistics of *Nummulites boninensis Hanzawa* (microspheric form)

Specimens	Diameter in mm.	No. of whorls	Thickness in mm.
1	43	33	10
2	56	39	12
3	27	37	8
4	38	30	8
5	35	34	
6	41	37	
7	40	38	
8	62		12

possesses 6 chambers in the first whorl and 12 chambers in the second whorl, and usually consists of 3 whorls as stated above.

The microspheric specimens of the present form show also a close resemblance to *Nummulites gizehensis* described by various authors from the various localities in the Tethys region in every respect, namely, the external form, size, number of whorls, number of chambers in whorls, etc., but the pattern of the meandriform septal filaments of the present form seems to be not identifiable with that of the specimens from its type locality, as shown in figures 8, 9 in plate 40 accompanying to the present paper. Moreover, in *N. gizehensis*, as pointed out by Flandrin and others, the whorls are dilated toward the proloculus and irregular. The features just cited are not found in the present specimens namely, the whorls are closely and regularly coiled throughout the life in the present form in general. Moreover, the pillars embedded in spiral lamellae are much more well developed in the present form than in *N. gizehensis* (Forskål). Therefore, I should like to propose for the present form a new species name, *N. boninensis*.

The external size of *Nummulites gizehensis* described by various authors from various localities are quoted for comparison, as follows.

Geological Horizon and Localities.—Eocene (Lutetian); Shizukazawa, Nankin Beach, Cocoanut Beach, Oki-mura, etc., Haha-jima

	Diameter	Thickness
Nummulites gizehensis Flandrin	15–36 mm.	4 – 7 mm.
Nummulites gizehensis Boussac	11–58 mm. (20–30 mm. in the majority)	
Nummulina gizehensis de la Harpe	50–60 mm.	8 –10 mm.
Nummulina gizehensis Rozloznik	24–49 mm.	4.8– 9 mm.
Nummulina gizehensis d'Archiac & Haime	40 mm.	3 – 8 mm.
Camerina gizehensis Doornink	11–48 mm. (12–30 mm. in the majority)	3 – 8 mm.

(Hillsborough Island), Ogasawara (Bonin) group. Figured type specimens from Shizukazawa. IGPS Coll., no. 20034.

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REINSTATEMENT OF THE GENUS HETEROSTEGINOIDES, AND THE CLASSIFICATION OF THE MIOGYPSINIDAE

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ABSTRACT—Re-examination of the internal structure of the Ecuadoran foraminifer described by Barker as *Miogypsina* aff. *M. panamensis* (Cushman) shows that the species is close to *Miogypsinopsis* Hanzawa, except that the proloculum of the former is subcentric while that of the latter is submarginal. Moreover, the young stage of the equatorial chambers of the Ecuadoran form as well as of *Miogypsinopsis* Hanzawa is similar to that of the genus *Miogypsinoides* Yabe and Hanzawa as well as *Miogypsinella* Hanzawa in that the equatorial chambers of the young stage are spiral in disposition, while the periembryonic chambers of the genera *Miogypsina* and *Miolepidocyclina* do not display a definite coil. The genus *Miolepidocyclina* Silvestri differs from the genus *Miogypsina* Sacco only in that the embryonic apparatus of the former is central, while that of the latter is submarginal. The Ecuadoran form is to *Miogypsinopsis* what the genus *Miolepidocyclina* is to *Miogypsina*. Since it seems to the writer that Barker's *Miogypsina* aff. *panamensis* (Cushman) may probably be assigned to the type from Panama when the latter is adequately illustrated for comparison, it would be better to restore the generic name *Heterosteginoides* Cushman (genotype, *H. panamensis*) long suppressed as a synonym of *Miolepidocyclina* Silvestri 1907, instead of establishing a new generic name for the Ecuadoran form. Tan Sin Hok has already proposed the new specific name *ecuadorensis*, which the writer considers unnecessary, for this form.

The writer proposes the use of two subfamilies, Miogypsininae and Miogypsinoidinae, in the family Miogypsinidae Tan Sin Hok, 1936.

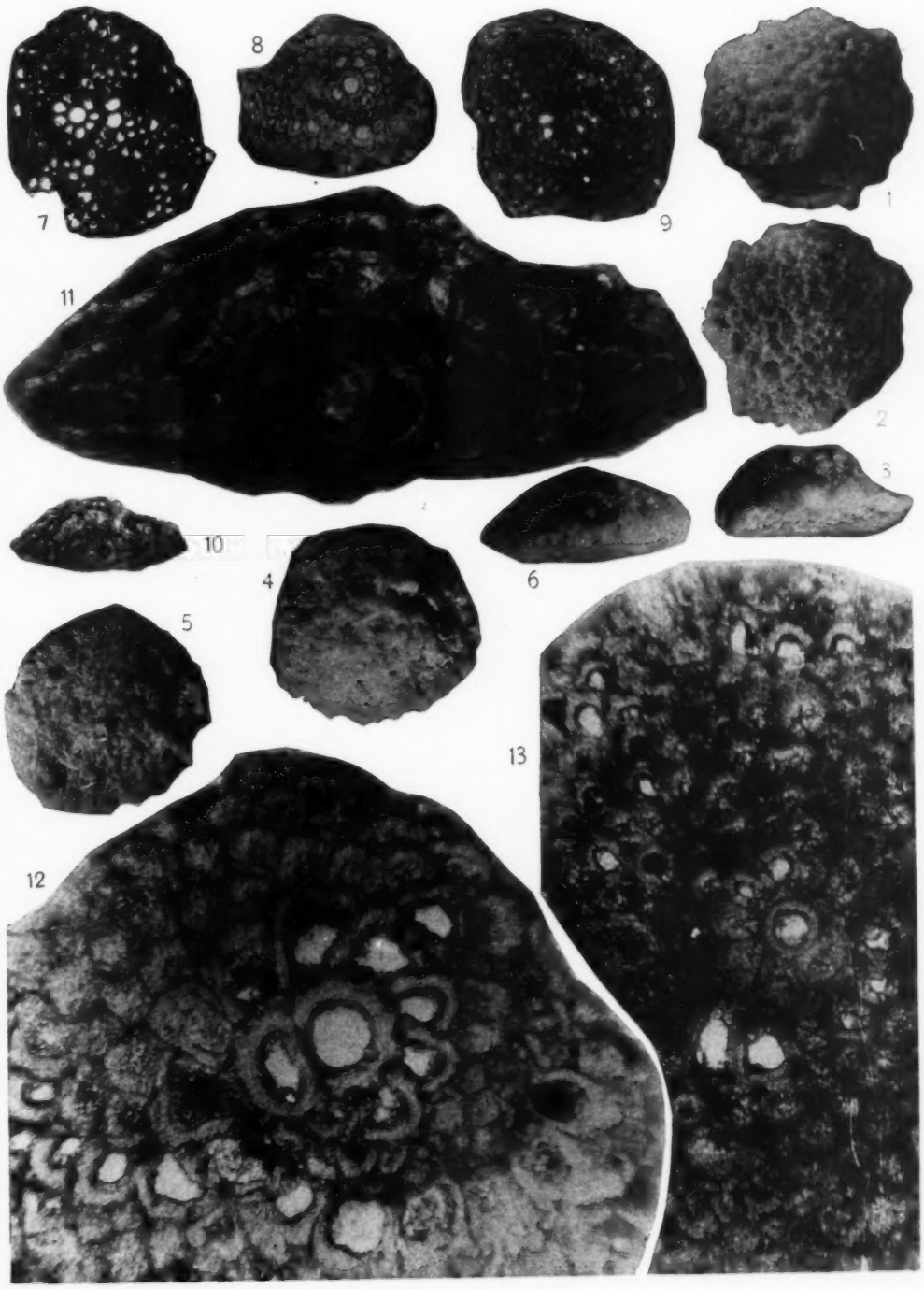
CUSHMAN (1918, p. 97) established a new genus *Heterosteginoides* on the basis of his new species *H. panamensis* from the Culebra formation of the Panama Canal Zone. He also (1919, p. 50) described another species of the genus, *H. antillea*, from Anguilla, the West Indies. Vaughan (1924, p. 813) distinguished two species among the Foraminifera described under the name *H. panamensis* by Cushman and proposed a new name, *Miogypsina cushmani* for one of these species. He later (1926, p. 1854) assigned *H. panamensis* and *H. antillea* to the genus *Miogypsina* Sacco. Since then the generic name *Heterosteginoides* Cushman has been suppressed as a synonym of *Miolepidocyclina* Silvestri, 1907, by Vaughan and Cole (1940, p. 331), Tan Sin Hok (1936, p. 58), Galloway (1933, p. 438) and the writer (1940, p. 778).

Tan Sin Hok (1936, p. 58), who divided *Miolepidocyclina* into two groups, the *complanata* type and *ecuadorensis* type, observed that *M. panamensis* (Cushman) is somewhat rotaloid and contains one and one-fourth whorls of spire in the young growth stage. He assigned the named species to the *complanata* type and proposed a new

EXPLANATION OF PLATE 41

Heterosteginoides panamensis Cushman. San Pedro, S.W. Ecuador, S.A. (I.G.P.S. Coll. Cat. No. 66280).

FIGS. *1*—Dorsal view of specimen a, ×20. (p. 261)
2—Ventral view of specimen a, ×20.
3—Peripheral view of specimen a, ×20.
4—Dorsal view of specimen b, ×20.
5—Ventral view of specimen b, ×20.
6—Peripheral view of specimen b, ×20.
7, 8, 9—Equatorial sections, ×20.
10—Vertical section cut through proloculum, ×20.
11—Same section as fig. 10, ×80.
12—Same section as fig. 8, ×80.
13—Same section as fig. 9, ×80.



Hanzawa, *Heterosteginoides panamensis*

specific name *ecuadorensis* for *Miogypsina* aff. *M. panamensis* Barker, from Ecuador, this being the central species of the *ecuadorensis* type.

Dr. Vaughan kindly shared a part of his extensive collections of various larger foraminiferal specimens from the Americas and Europe with me when I was at the Scripps Institution of Oceanography, La Jolla, California, in 1936. Recently I made thin sections of several specimens of Foraminifera from San Pedro, S.W. Ecuador, among the collections mentioned above. These specimens seem to be the paratypes, which were described by Dr. Barker (1932, p. 279) as *Miogypsina* aff. *panamensis* (Cushman) and *Miogypsina* cf. *staufferi* Koch. These specimens are small in size and separable into conical and lenticular forms by the external features. But there are some transitions between these two forms. I now assign both the forms to one and the same species, since the features of the proloculum, periembryonic chambers, and equatorial chambers are quite the same in these two types. The conical form consists of an equatorial layer of chambers and some lateral layers of chambers above and below the former. Since the equatorial chambers are situated near the base of the cone, more numerous lateral layers of chambers are superposed on the conical side of the test than those of the basal side of the test. A spherical proloculum is somewhat excentrically located and the periembryonic chambers, subquadrangular in equatorial section, are spirally disposed around the proloculum, forming $1\frac{1}{2}$–$1\frac{1}{4}$ whorls. The first whorl is completed around the proloculum by 8 chambers without exception as shown in Barker's paper, (1932, pl. 16, fig. 7). I made 8 equatorial sections of the foraminifer. The later equatorial chambers are diamond-shaped and accrued concentrically around the periembryonic chambers.

I discriminated five genera, (1940, p. 778) *Miogypsinella* Hanzawa, *Miogypsinoides* Yabe & Hanzawa, *Miogypsinopsis* Hanzawa, *Miogypsina* Sacco, and *Miolepidocyclina* Silvestri in the family Miogypsinidae Tan Sin Hok. The genus *Miogypsinoides* is easily distinguished from the other genera by having compact lateral layers instead of lateral chambers. It is also distinguishable from the genera *Miogypsina* and *Miolepidocyclina*, because the periembryonic chambers are spirally disposed in the former, while the latter two lack such features. The genus *Miogypsinella* is indistinguishable from the genus *Miogypsinoides* in equatorial section alone. But the former is the most primitive type of the family Miogypsinidae, and rotaloid in structure in the young stage of growth of the test. Several rows of equatorial chambers are accrued on the distal periphery of the juvenarium. A few rudimentary lateral chambers are sometimes seen in the lateral layers in the positions being considered as places where the spiral lamellae of the rotaloid shell come to contact each other. I distinguished the genus *Miogypsinopsis* from the genus *Miogypsina*, since the former shows the same features as the genus *Miogypsinoides* in the equatorial section, though the genera *Miogypsinopsis* and *Miogypsina* otherwise resemble each other.

The form of foraminifer from Ecuador now in question resembles the genus *Miolepidocyclina* with respect to the proloculum, which is some distance from the periphery of the test, but the former is distinguishable from the latter by the periembryonic chambers of definite coils around the proloculum, while the embryonic apparatus and the disposition of the periembryonic chambers of the latter are quite different as cited later. In other words, the Ecuadoran form is to the genus *Miogypsinopsis* what the genus *Miolepidocyclina* is to the genus *Miogypsina*.

The features of the equatorial chambers of *Heterosteginoides panamensis* Cushman seem to be not yet adequately illustrated. For this reason Barker could not properly identify the Ecuadoran form with this species. If the Ecuadoran form is safely assigned to *Heterosteginoides panamensis* Cushman and it is admitted that the Ecuadoran form is generically distinguishable from any genera of the family Miogypsinidae ever proposed, the generic name *Heterosteginoides* Cushman, 1918 which has long been suppressed as a synonym of the genera *Miolepidocyclina* Silvestri, 1907 and *Miogypsina* Sacco, 1893, can be used again for the species *panamensis* Cushman. Though I am not now quite sure that the Ecuadoran form of foraminifer is specifically as well as generically identical with *Heterosteginoides pana-*

mensis Cushman from the Panama Canal Zone, I believe now it is more hazardous to accept Dr. Tan's new specific name *Miolepidocyclina ecuadorensis* for Dr. Barker's *Miogypsina* aff. *panamensis* than to refer the latter to the type from the Panama Canal Zone without query. Therefore, I do not want to venture to propose a new generic name for the Ecuadoran form designating *Miolepidocyclina ecuadorensis* Tan Sin Hok as the genotype.

Dr. Vaughan (1926, p. 1855) once pointed out that *M. panamensis* has much resemblance to *Helicolepidina*. The Ecuadoran form now in question resembles in general configuration *Helicolepidina paucispira* Barker and Grimsdale (1936, p. 243), but the former is provided with diamond-shaped equatorial chambers and the canal system, whereas the latter has arcuate equatorial chambers and lacks the canal system.

According to Vaughan, the upper part of the Culebra formation which yields *Heterosteginoides panamensis* Cushman is the uppermost Oligocene, possibly Lower Miocene in age.

I think now the Family Miogypsinidae Tan Sin Hok, 1936 may be divided into two subfamilies, viz. (1) Miogypsininae and (2) Miogypsinoidinae. In the first subfamily, the embryonic apparatus consists of two chambers; the heteroconch being spherical, the deuteroconch being hemispherical or somewhat irregular in shape, usually larger than the heteroconch, very rarely equal to the latter in diameter, always placed on the proximal margin of the test or situated nearer the proximal margin than the heteroconch; the periembryonic chambers disposed around the heteroconch in bilateral symmetry or in incomplete coil and decreasing gradually in size towards their last chamber. In the second subfamily, the first two chambers may or may not be interpreted as consisting of an embryonic apparatus, the proloculum being spherical, the second chamber being hemispherical, equal to the proloculum in diameter; the periembryonic chambers being subquadrangular in equatorial section, as a whole forming definite coils around the proloculum, increasing gradually in size towards their last chamber. The features of the embryonic and periembryonic chambers mentioned above are most characteristic of these two subfamilies. To the subfamily Miogypsininae belong two genera, *Miogypsina* Sacco and *Miolepidocyclina* Silvestri. Both genera possess the lateral chambers, the embryonic apparatus is marginal in the genus *Miogypsina* Sacco and subcentric in the genus *Miolepidocyclina* Silvestri. To the subfamily Miogypsinoidinae, belong four genera, *Miogypsinoides* Yabe and Hanzawa, *Miogypsinella* Hanzawa, *Miogypsinopsis* Hanzawa, and *Heterosteginoides* Cushman. The last two genera cited possess the lateral chambers, while the first named two genera are provided with compact lateral layers instead of the lateral chambers. The proloculum is marginal in the first three genera, while it is subcentric in the last genus.

Family Miogypsinidae Tan Sin Hok, 1936
Subfamily Miogypsininae

Embryonic apparatus marginal: *Miogypsina* Sacco, 1893.
Embryonic apparatus subcentric: *Miolepidocyclina* Silvestri, 1907

Subfamily Miogypsinoidinae

Proloculum marginal: *Miogypsinoides* Yabe & Hanzawa, 1928 (without lateral chambers)
Proloculum marginal: *Miogypsinella* Hanzawa, 1940 (with rudimentary lateral chambers)
Proloculum marginal: *Miogypsinopsis* Hanzawa (with lateral chambers)
Proloculum subcentric: *Heterosteginoides* Cushman, 1918 (with lateral chambers)

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JOURNAL OF PALEONTOLOGY, VOL. 21, NO. 3, PP. 264–267, PL. 42, MAY 1947

BELLEROPHONT MUSCLE SCARS

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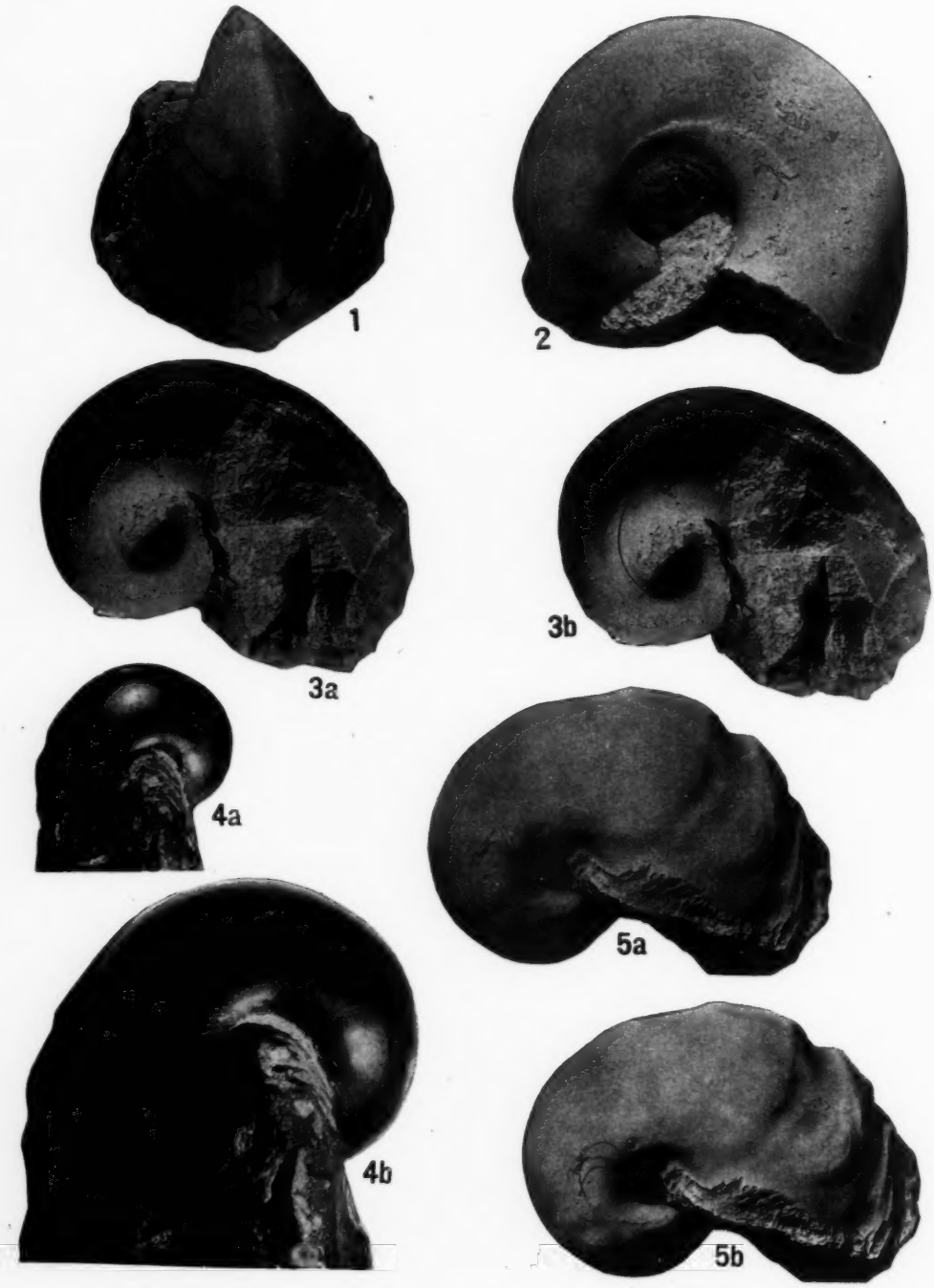
ABSTRACT—Wenz's report of the discovery of muscle scars on a specimen of *Cyrtonella mitella* (Hall) and his reclassification of the major categories of the Gastropoda based thereon are briefly discussed and evaluated. The discovery of muscle scars on several specimens of three species referable to two undoubted bellerophont genera is reported. These muscle scars are entirely different from those of *Cyrtonella* and are in accord with the generally accepted view that the bellerophonts were streptoneurous, not primitively orthoneurous as Wenz supposed.

WHEN a paleontologist has to deal with fossils belonging to groups without living representatives, he must grasp at any skeletal features that will give him clues that may be helpful in understanding the soft anatomy. Such a group is the bellerophonts, extinct since Triassic time unless the rare genus *Zeidora* Adams, the soft anatomy of which is seemingly unknown, should prove to be a bellerophont surviving through adaptation to rock-clinging. Hence anything that can throw further light on the soft anatomy of the bellerophonts is of interest.

In December 1937 the late Doctor W. Wenz of Frankfort-am-Main wrote me of his most interesting conclusion that the Tryblidiacea with their simple, cap-shaped shells and six or eight symmetrical pairs of muscle scars were not fossil Patellacea but very primitive gastropods ancestral to the Amphineura on one hand and to the bellerophonts on the other. He regarded both the Tryblidiacea and the Bellerophontacea as primitively orthoneurous, that is to say, he thought that the torsion that characterizes all the more advanced gastropods had not taken place in either. If this were true for the bellerophonts, as it most probably is for the Tryblidiacea, then the bellerophonts should show paired dorsal muscle scars as the Tryblidiacea do. This was to be the test of his hypothesis so far as the bellerophonts were concerned. He wrote to me to ask if I had ever observed the muscle scars in any bellerophont, particularly in the Cyrtolididae, which he regarded as the most primitive of the bellerophonts. At the time it was necessary to reply that I had never observed the muscle scars of any bellerophont and, as far as I knew, no one else had. However it was not long before chance seemed to provide an answer to his question, for early in 1939 Dr. Tsun-Yi Yang brought to my laboratory at Princeton a collection of gastropods from the Devonian Traverse group of Michigan on which he was working as a part of his doctorate thesis at Yale. In the collection was a specimen of *Cyrtonella mitella* (Hall) with the pyritized steinkern so beautifully preserved that it showed two pairs of dorsal muscle scars almost precisely as Wenz's hypothesis demanded. At that time *Cyrtonella* was commonly referred to the Cyrtolitidae although not without reservations. This seemed to be so startling a fulfillment of prediction that I suggested to Yang that he write Wenz and tell him of it. This he did, sending Wenz some photographic prints to support his statements. Wenz immediately published Yang's discovery and his photographs and, finding his hypothesis so promptly confirmed, as he thought, revised the classification of the gastropods by setting up a new subclass, the Amphigastropoda, diagnosed as bilaterally symmetrical and primitively orthoneurous, with the shell bowl-shaped, conical or symmetrically spiral (Wenz, 1940). This new subclass included the Tryblidiacea and the Bellerophontacea of Wenz, 1938.

On theoretical grounds, which I shall not go into at this time, I was unable to follow Wenz as to the bellerophonts as a whole, although his case appears to be a good one so far as *Cyrtonella* is concerned. But *Cyrtonella* has always been a puzzling and doubtful bellerophont on several scores, so that there is no serious shock in finding in it characters that remove it from the bellerophonts.

Most workers in the last fifty years, except Wenz, have believed the bellerophonts to be streptoneurous for various more or less compelling reasons. Hence, although Wenz's



Knight, Bellerophont Muscle Scars

UNIV. OF MICH.

demonstration that the doubtful bellerophont *Cyrtonella* is most probably orthoneurous came as no great surprise, his assumption that all bellerophonts are likewise orthoneurous was difficult to accept. Since the support for Wenz's hypothesis was found in the muscle scars of *Cyrtonella* an additional impetus was provided for searching for the muscle scars of more typical bellerophonts. The transfer of my activities to the United States National Museum, where large collections of bellerophonts were available to me, provided an opportunity for such a search, and it is gratifying not only that the search was successful in respect to two typical bellerophont genera but that the findings support the hypothesis that the true bellerophonts were probably streptoneurous instead of orthoneurous as Wenz supposed.

The molluscan muscle scar is basically a depression in the inner layers of the shell, a depression created by the removal of some of the shelly matter for the emplacement of the muscle. The depression is deep in massive, thick shells and shallow in thin shells. Its surface is often affected by rough or irregular secondary deposits. It moves toward the margin or aperture of the shell, as the muscles move by the general growth of the animal, through removal of shell matter in the direction of growth, and filling in behind. The depressed scar often shows lineation parallel with the advancing margins of the scar. The scars are conspicuous in pelecypods, particularly in those with thick shells, and in gastropods with open, cuplike shells such as are characteristic of those adapted to rock-clinging. In gastropods with the helicoidal, asymmetrical shell, so characteristic of the vast majority, there is a single asymmetrical retractor muscle fastened to the columella well within the aperture. In such forms the scar is shallow, obscure, seldom noticed and rarely described.

If the bellerophonts are streptoneura so primitive that lateral asymmetry had not developed as most sudents of the last 50 years, except Wenz, have supposed, there should be a single symmetrical pair of adductor muscles, each element attached to the columella on each side or on the inner surface of the shell very near the columella. Until recently I had never observed muscle scars on any bellerophont nor have I met

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EXPLANATION OF PLATE 42

FIG. *1*—*Cyrtonella mitella* (Hall) Slightly oblique dorsal view, ×4, of the specimen mentioned in the text, a pyritized cast of the interior. Photograph by Yang. Note the two pairs of posterior dorsal tryblidian muscle scars. In advance of each scar is a "shadow" scar, the meaning of which is unknown. Somewhat similar "shadow" scars are known in advance of the scars of *Archaeophiala antiquissima* (Hisinger), [See Knight, 1942, pl. 3, fig. 36] and of other tryblidians. (p. 264)

2—*Bellerophon* sp. indet. View, ×2, of the right side of limestone cast of the interior. Note the sharply raised area around the columellar region. This is thought to be the cast of the scar of the right retractor muscle. The scar was unusually deep for the genus as the species is one with an unusually thick shell. (p. 266)

3a–b—*Bellerophon gibsoni* White. View, ×1, of the right side of limestone cast of the interior. The scar area is bounded by a faint line, shown just as it is in *3a* and retouched for emphasis in *3b*. It has the same shape as the scar in the foregoing species, but as *B. gibsoni* has a much thinner shell its scars are very faint. (p. 266)

4a–b—*Sinuites cancellatus corrugatus* (Hall). *4a*, Slightly oblique view of the left side of fine, black limestone cast of the interior of a small specimen, ×2. *4b*, Another view of the left side of the same specimen (USNM 111935), ×4. This specimen showed the best scars of the several that show them, but they are so faint that ammonium chloride obliterated them entirely. The only way that they could be made to show photographically was to arrange the lighting on the uncoated specimen so that an area of highlight was reflected directly from the scar. If the reader will examine the high-light reflection to the right of the columellar region he will see not only the scar area but the crescent-shaped lineations parallel to the anterior margin. (p. 266)

5a–b—*Sinuites cancellatus corrugatus* (Hall). View of right side of black limestone cast of the interior, USNM 111934, ×2. On this specimen, a few of the crescentic lineations of the scar are strong enough to be seen with a coating of ammonium chloride. They lie just to the left of the columellar region on *5a* and are emphasized by retouching on *5b*. (p. 266)

with any mention of them in the literature. Actually the probability of being able to observe such scars would be poor, for they would lie far within the aperture, commonly filled with matrix, and, if they are like the single scar of the helicoidal, asymmetrical gastropods, probably homologous with the left-hand scar of the bellerophonts, they would be shallow and very faint, especially in thin-shelled forms. The only state of preservation that would offer any probability of displaying observable scars would be natural casts of the interior of shells in a very fine matrix. Here we might expect that depressions in the shell, such as the scars of thick-shelled forms, would be recorded as corresponding elevations or that the characteristic lineation parallel to the advancing margins of the scar might be recorded, if the matrix were sufficiently fine, for thin-shelled forms.

In going through the collections at the United States National Museum I found a number of natural casts of the interior of bellerophonts showing unmistakable records of the muscle scars. Three species of two typical bellerophont genera showed the scars, one species being represented by several specimens. The scars in all examples fulfilled expectations in that they are a single symmetrical pair, placed at the juncture of the distal ends of the columella and the side walls of the shell. Where it can be measured the anterior end of the scar is a little more than one-half whorl back from the apertural margins. I shall describe the scars of each species below.

SINUITES CANCELLATUS (Hall), 1847
Plate 42, figures 4a–b, 5a–b

The scars are shown more or less clearly on several specimens of both the typical variety and the supposed variety *corrugatus* in three collections, all from the Trenton limestone, USNM no. 79202 from 2 miles northeast of Middleville, New York; USNM nos. 92443 and 111935 from Trenton Falls, New York, and USNM nos. 92449 and 111934 from Poland Bridge, Poland, Herkimer County, New York. The matrix is a very fine, black calcilutite that preserves the impressions of fine details exquisitely. The shell was thin and the muscle scars consequently hardly impressed. The impressions of the fine, crescentic lineations paralleling the narrowly rounded advancing margin of the scar are preserved more or less clearly by virtue of the exceptionally favorable matrix. The anterior margin of the scar is slightly more than one-half a whorl back from the apertural margin. The scar itself is manifested on the crest of what might be called the circumbilical angulation of the internal cast, that is to say on the inner face of the shell in the groove just at the distal ends of the columellae. The anterior end is rounded; the posterior end extends back under the matrix on all specimens and has not been observed.

The markings are so very fine that they were exceedingly difficult to photograph.

BELLEROPHON GIBSONI White, 1882
Plate 42, figures 3a–b

The scars are shown rather faintly but I think unmistakably on the large specimen under USNM no. 64339. This specimen, a cast of the interior in crystalline grey limestone, is probably the holotype of the species. It is recorded from the St. Louis limestone at Greencastle Junction, Indiana. The inner end of the scar appears to begin on the columella and to spread gradually onto the side-walls of the shell. Since the apertural part of the cast is broken it is impossible to say how far it extended toward the aperture. The scar was not deeply impressed in the shell, possibly because the shell, White to the contrary notwithstanding, is not a particularly thick one for the genus. It shows no lineations parallel with the anterior end. The upper margin of the cast of the scar is bounded by an exceedingly fine raised line.

BELLEROPHON sp. indet.
Plate 42, figure 2

This specimen is the largest of four under USNM no. 51074. The species is not determinable but enough shell remains to show that it is properly referred to the genus *Bellerophon*. The stratigraphic position is given as "Coal Measures" (Pennsylvanian) and the locality as Kansas City, Missouri. The other three specimens seem to be different specifically and probably generically. A small part of the very thick shell of the specimen is preserved. The scar (as shown by its counterpart on the internal cast) was

deep, probably because of the very thick shell. Its upper margin was sharply impressed. The end of the scar away from the aperture began on the columella and spread onto the sidewalls of the shell toward the aperture. Anteriorly the scar becomes gradually broader and shallower until all trace of it is lost. The apertural end of the cast is broken away, and it is impossible to say how close the scar approached the apertural margin. Such lineations as are shown are parallel to the deeply impressed upper margin of the scar rather than to the anterior end.

SUMMARY

Although the several paired dorsal muscle scars of *Cyrtonella* seem to ally that genus to the Tryblidiacea as suggested by Wenz, Wenz seems to have gone too far when he attributed characters of the same sort to the other, more typical bellerophonts. The muscle scars of two typical bellerophont genera, *Sinuites* and *Bellerophon*, are described. These show that these forms had a single symmetrical pair of retractor muscles fastened to the columellae, or to the inner surface of the side walls of the shell close to the distal ends of the columellae, deep within the aperture. These findings support the view arrived at from other evidence that the true bellerophonts were streptoneurous and laterally symmetrical in their soft anatomy as well as in their shells. *Cyrtonella* is accepted as being primitively orthoneurous and to be included with the Tryblidiacea, not the Bellerophontacea.

There is no new evidence bearing on *Cyrtolites* and its allies. Their shell characters ally them to the other bellerophonts, and until evidence to the contrary is discovered it will be assumed that they are true bellerophonts with the organization of the soft parts appropriate to that group.

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PLIOCENE FRESH-WATER MOLLUSKS FROM NORTHERN UTAH

TENG-CHIEN YEN

ABSTRACT—A molluscan fauna from the Pliocene fresh-water Salt Lake formation near Logan, Utah is described and illustrated. The collection contains three species of pelecypods and seventeen species of gastropods. Of the gastropods, one genus, *Anculopsis*, and ten species and subspecies are given new names.

THE material treated in the present paper came from a deposit located in Section 15, T. 13 N., R. 2 W., on the boundary between Cache and Box Elder Counties, about 14 miles northwest of Logan, Utah, considered to be a part of the Salt Lake formation. The collection was made by Dr. J. Stewart Williams, of Utah State Agricultural College, through whose kindness I am given the privilege of studying this interesting group of mollusks.

The fossils are imbedded in a poorly consolidated matrix of fine sand that is comparatively easy to remove, and most of the specimens are well preserved. The molluscan fauna consists of three species of pelecypods in three genera representing two families, and seventeen species of gastropods in eleven genera representing eight families. Among them one genus and ten species and subspecies of gastropods are herein described as new. Although ostracodes are also quite abundant, few remains of other organisms were found in the collection, except coarse impressions of a sedgelike plant in some harder limy layers.

A few apparently casual collections of late Tertiary freshwater mollusks provide previous records from the Great Basin area. Gabb's description of species from southern Idaho in 1866 and Meek's species from Fossil Hill, Hot Spring Mountains, Nevada, in 1870 paved the way for the later works by Call, Dall, Henderson, Chamberlin and Berry, as well as myself. However these papers, based on incidental collections do not present fully the fauna that existed in late Tertiary times over the Great Basin area, and our knowledge of the fresh-water faunas is still insufficient for assured application to stratigraphy. Many additional data are needed, and the present report is therefore offered as a modest contribution to the subject.

In completing this paper, I wish to thank first of all the administrative officers of the Geological Society of America for their continuous support of my studies on the fresh-water mollusks in the continental deposits of the western United States. I also want to express my appreciation to Dr. John B. Reeside, Jr., for his helpful advice and untiring encouragement to my work; and also to Dr. Henry A. Pilsbry, of the Academy of Natural Sciences of Philadelphia for his expert suggestions in this work and for the use of the rich collection of mollusks in his department for comparison.

COMPOSITION AND AGE OF THE FAUNA

The present collection contains the following species of fresh-water mollusks:

Anodontidae:
Anodonta cf. *A. kettlemanensis* Arnold
Sphaeriidae:
Sphaerium idahoense Meek
Pisidium woodringi Yen
Valvatidae:
Valvata incerta Yen, n. sp.
Amnicolidae:
Fluminicola perditicollis Pilsbry
Fluminicola yatesiana utahensis Yen. n. subsp.
Pilsbryus antiquus utahensis Yen, n. subsp.
Pilsbryus cf. *P. campbelli* (Dall)
Viviparidae:
Lioplax utahensis Yen, n. sp.
Pleuroceratidae:
Anculopsis bicarinata Yen. n. gen. and sp.
Anculopsis houghterlingi Yen, n. sp.
Ancylidae:
Payettia micra Yen, n. sp.
Lancidae:
Lanx cf. *L. undulata* (Meek)
Physidae:
Physa sp. undet.
Planorbidae:
Pompholopsis utahensis Yen, n. sp.
Pompholopsis planospiralis Yen, n. sp.

Pompholopsis minima Yen, n. sp.
Pliopholyx reesidei Yen, n. sp.
Angulorbis monocarinatus (Chamberlin and Berry)
Angulorbis annectans (Chamberlin and Berry)

In addition to the molluscan species listed above, ostracodes are abundant in the material. Other kinds of animals were not found, but the present collection can not serve as positive evidence for their absence.

The presence of numerous new species in the collection implies that the total molluscan fauna is a rich one, and the diversification of the mollusca found in this single collection indicates that the extinct body of water in which they lived was of large size, for otherwise it would not have met the differing requirements for existence of so great a variety of forms.

Since the nonmarine fossiliferous deposits exposed over the Great Basin area uncomformably overlie at many places the pre-Tertiary rocks, the age determination of such deposits must depend in considerable part upon the faunal evidence. As far as the present collection is concerned, the fresh-water molluscan remains furnish the only available means of attacking this problem, and to supply a better basis for judgement, a comprehensive analysis and comparison of the fossil fresh-water molluscan faunas that have been recorded from places west of the continental divide is given below.

DISTRIBUTION OF LATE TERTIARY FRESH-WATER MOLLUSKS IN CALIFORNIA, UTAH AND SOUTHERN IDAHO

Among all the fossil mollusks familiar to me, the group of species described by Chamberlin and Berry (1933) from a locality near Collinston, Utah, seems to bear the closest resemblance to the forms recorded in the present paper. That collection, however, is not available for comparison and will not be considered further. Of those records I am able to quote with reasonable certainty, I give the molluscan faunas in an accompanying table. The letters indicate the source of the list, as follows:

A—Basal part of Tulare formation at various localities in the Kettleman Hills, California, H. A. Pilsbry, 1934.
B—"Salt Lake Group," about 14 miles northwest of Logan, Utah. Reported in the present paper.
C—Idaho formation exposed in places in Snake Valley, South Idaho. W. H. Dall, 1924.
D—Idaho formation exposed near Hammett, southern Idaho. Teng-Chien Yen, 1944.
E—"Salt Lake formation," about 9 miles northwest of Montpelier, southeastern Idaho. Teng-Chien Yen, 1946.

By examining the records given in the table, it may be noted that the assemblage of molluscan fauna in the present collection (in Column B) has more in common with the fauna of the Idaho formation (in Columns C and D) than with those given in Columns A and E.

The great difference in genera and species between Columns A and B suggests considerable difference in age rather than in ecology, since both deposits are generally believed to be of lacustrine origin. Moreover, by analysing individually these two columns, it may be noted that the fauna from the basal part of the Tulare formation shows a more modern aspect. The fauna from Utah has at least five genera that are extinct, or so far not shown in the living fauna. Therefore it may be regarded that the base of the Tulare formation is younger than the present deposit. Current opinion in regard to the age of the base of the Tulare formation assigns it to the Lower Pleistocene or Upper Pliocene. If the Tulare is of Lower Pleistocene age, the Utah deposit may safely be considered as of Pliocene age.

The fauna from Utah has even less in common with that shown in Column E, from the "Salt Lake formation" in southern Idaho, which on grounds presented elsewhere, the writer (1946) assigns to a Miocene age.

As the table indicates, the molluscan fauna of the present collection shows a fairly close relationship to that of the Idaho formation (Columns C and D), although the differences are evident in both generic and specific composition. These differences may eventually justify separation into smaller age units, but such division must await further and broader studies of the fossil fauna and flora. In the meanwhile the vertebrate fossils indicate that the Idaho formation contains both a Pliocene fauna in the lower beds and a Pleistocene fauna in the higher beds. The fossil plants are considered

	A	B	C	D	E
Pelecypoda					
Anodonta kettlemanensis	×	—	—	—	—
Anodonta cf. *A. kettlemanensis*	—	×	—	—	—
Sphaerium cooperi	×	—	—	—	—
Sphaerium idahoense	—	×	×	×	—
Sphaerium kettlemanse	×	—	—	—	—
Sphaerium rugosum	—	—	×	—	—
Pisidium compressum praecompressum	×	—	—	—	—
Pisidium woodringi	—	×	—	×	—
Gastropoda					
Valvata incerta	—	×	—	—	—
Valvata humeralis californica	×	—	—	×	—
Valvata humeralis densestriata	×	—	—	—	—
Valvata virens platyceps	×	—	—	—	—
Valvata multicarinata	—	—	—	—	×
Valvata cf. *V. octonaria*	—	—	—	—	×
Amnicola bithynoides	—	—	—	×	—
Amnicola longiqua	×	—	—	—	—
Amnicola puteana	×	—	—	—	—
Amnicola micra	—	—	—	—	×
Hydrobia andersoni	×	—	—	—	—
Hydrobia andersoni sterea	×	—	—	—	—
Hydrobia birkhauseri	×	—	—	—	—
Fluminicola kettlemanensis	×[*1]	—	—	—	—
Fluminicola percarinata	×*	—	—	—	—
Fluminicola perditicollis	×*	×	—	—	—
Fluminicola pilula	×*	—	—	—	—
Fluminicola siegfusi	×*	—	—	—	—
Fluminicola spiralis	×	—	—	—	—
Fluminicola weaveri	—	—	—	×	—
Fluminicola williamsi	×*	—	—	—	—
Fluminicola yatesiana	×	—	—	—	—
Fluminicola yatesiana utahensis	—	×	—	—	—
Brannerillus acutispirus	—	—	—	—	×
Brannerillus idahoensis	—	—	—	—	×
Brannerillus physispirus	×	—	—	—	×
Brannerillus involutus	×	—	—	—	—
Brannerillus involutus threma	×	—	—	—	—
Brannerillus i. praeposterus	×	—	—	—	—
Pyrgulopsis carinata	—	—	—	×	—
Pyrgulopsis tropidogyra	×	—	—	—	—
Pyrgulopsis vincta	×	—	—	—	—
Pyrgulopsis (?) polynematica	×	—	—	—	—
Calipyrgula carinifera	×	—	—	—	—
Calipyrgula ellipsostoma	×	—	—	—	—
Calipyrgula stewartiana	×	—	—	—	—
Littoridina woodringi	×	—	—	—	—
Pilsbyrus antiquus	—	—	×	×	—
Pilsbryus antiquus utahensis	—	×	—	—	—
Pilsbryus cf. *P. campbelli*	—	×	—	—	—
Pilsbryus campbelli	—	—	×	—	—
Pilsbryus superbus	—	—	—	×	—
Lioplax utahensis	—	×	—	—	—

	A	B	C	D	E
Anculopsis bicarinata	—	×	—	—	—
Anculopsis houghterlingi	—	×	—	—	—
Goniobasis arnoldiana	×	—	—	—	—
Goniobasis kettlemanensis	×[1]	—	—	—	—
Goniobasis k. woodringi	×	—	—	—	—
Goniobasis taylori	—	—	×	×	—
Goniobasis taylori calkinsi	—	—	×	—	—
Payettia dalli	—	—	×	×	—
Payettia micra	—	×	—	—	—
Lanx undulata	—	—	×	×	—
Lanx cf. *L. undulata*	—	×	—	—	—
Orygoceras arcutum	—	—	×	×	—
Orygoceras crenulatum	—	—	×	—	—
Orygoceras idahoense	—	—	×	—	—
Orygoceras tricarinatum	—	—	×	—	—
Orygoceras tuba	—	—	×	—	—
Lymnaea fluminicoloides	—	—	—	—	×
Lymnaea idahoensis	—	—	—	—	×
Lymnaea petuluma	—	—	—	—	×
Lymnaea umbilicalis	—	—	—	—	×
Physa humerosa	×	—	—	—	—
Physa waitsi	×	—	—	—	—
Physa sp. undet.	—	×	—	—	—
Armiger subcostatus	—	—	—	—	×
Armiger subcostatus obsoletus	—	—	—	—	×
Vorticifex binneyi	—	—	×	—	—
Vorticifex tryoni	—	—	×	—	×
Vorticifex tryoni concava	—	—	—	—	×
Carinifex brevispira	—	—	—	—	×
Carinifex sanctaeclarae marshalli	×	—	—	—	—
Menetus centervillensis	×	—	—	—	—
Planorbifex vanvlecki	×	—	—	—	—
Planorbifex idahoensis	—	—	—	—	×
Parapholyx cf. *P. effusa*	×	—	—	—	—
Pliopholyx idahoensis	—	—	—	×	—
Pliopholyx reesidei	—	×	—	—	—
Pompholopsis minima	—	×	—	—	—
Pompholopsis planospiralis	—	×	—	—	—
Pompholopsis utahensis	—	×	—	—	—
Angulorbis multicarinatus	—	—	—	×	—
Angulorbis monocarinatus	—	×	—	—	—
Angulorbis annectus	—	×	—	—	—
Papyrotheca idahoensis	—	—	—	—	×

[1] * indicates species reported from the beds of San Joaquin formation in Kettleman Hills, California, which is generally considered to be of Pliocene age.

to be of Pliocene age and the recorded molluscan fauna is considered Pliocene. The assignment of a Pliocene age to the fauna from Utah and to its containing rocks seems to be the most logical procedure, with perhaps some indication that it is of later Pliocene age.

SYSTEMATIC ACCOUNT OF SPECIES

Family Anodontidae

ANODONTA cf. A. KETTLEMANENSIS Arnold

Plate 43, fig. 1

Anodonta kettlemanensis, ARNOLD, 1909, U. S. Geol. Surv., Bull. 396, p. 91, pl. 30, fig. 10.

Two valves in the present collection resemble young forms of this species, but the specimens are not well enough preserved for specific identification.

Figured specimen.—U.S.N.M. *559991.*

Family Sphaeriidae

SPHAERIUM IDAHOENSE Meek

Plate 43, fig. 2a, b

Sphaerium idahoense, MEEK, 1870, Acad. Nat. Sci. Philadelphia, Proc., 22, p. 57.
Sphaerium idahoense MEEK, 1877, U. S. Geol. Surv. 40th. Parallel, 4 (1), p. 183, pl. 16, fig. 1.

A single valve of large size and a few smaller ones represent this species in the collection. Its external view agrees well with Meek's original figure.

A few very small valves are characterized by roundly rectangular outline and cord-like concentric ridges over the surface. They resemble *Sphaerium meeki* Dall, but are probably the young forms of *S. idahoense.*

Figured specimen.—U.S.N.M. *559992.*

PISIDIUM WOODRINGI Yen

Plate 43, fig. 3.

Pisidium exiguum, YEN, 1944, Jour. Paleontology, 18 (1), p. 108, fig. 4.
Pisidium woodringi, YEN, 1945, Nautilus, 59 (1), p. 34

A number of valves contained in the collection indicate the common occurrence of this species in the deposit. They resemble very closely the form described from the Idaho formation, but the hinge structure of the "Salt Lake" specimens, though similar in type, seems to be heavier.

Figured specimen.—U.S.N.M. *559993.*

Family Valvatidae

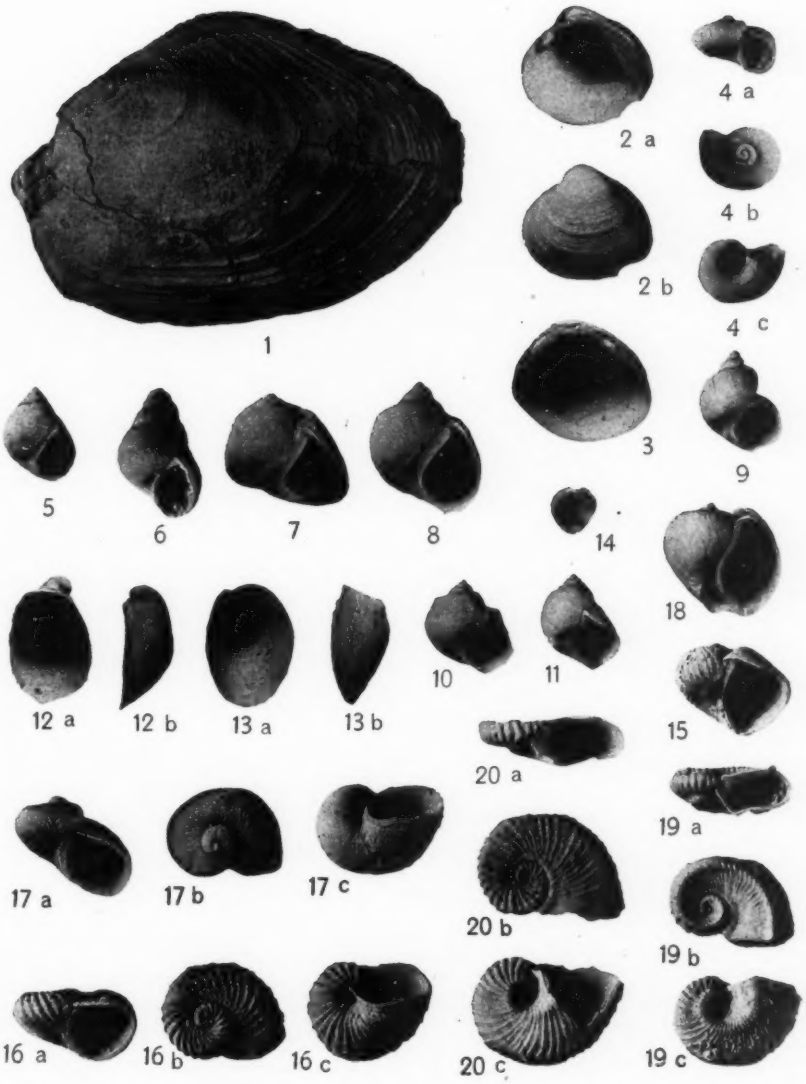
VALVATA INCERTA Yen, n. sp.

Plate 43, fig. 4a, b, c

Shell of small size and helicoid outline, low spire and rapidly enlarging body whorl. Whorls increasing rapidly in size, gently convex and bearing costulate and fine lines of growth, the costulate sculpture traceable only on the better preserved part of whorl-surface. Suture well impressed. The last part of the body whorl has the tendency to be inclined to form an angle against the penult whorl. The aperture is almost circular in outline, having its peristome continuous and

EXPLANATION OF PLATE 43

FIG. *1*—*Anodonta* cf. *A. kettlemanensis* Arnold. ×1. (p. 272)
2a, b—*Sphaerium idahoense* Meek. ×1. (p. 272)
3—*Pisidium woodringi* Yen. ×6. (p. 272)
4a, b, c—*Valvata incerta* Yen, n. sp. ×6. (p. 272)
5—*Fluminicola perditicollis* Pilsbry. ×2. (p. 273)
6—*Fluminicola yatesiana utahensis* Yen, n. subsp. ×6. (p. 273)
7—*Pilsbryus antiquus utahensis* Yen, n. subsp. ×2. (p. 273)
8—*Pilsbryus* cf. *P. campbelli* (Dall). ×2. (p. 273)
9—*Lioplax utahensis* Yen, n. sp. ×1. (p. 273)
10—*Anculopsis bicarinata* Yen, n. sp. ×1. (p. 274)
11—*Anculopsis houghterlingi* Yen, n. sp. ×1. (p. 274)
12a, b—*Payettia micra* Yen, n. sp. ×4. (p. 275)
13a, b—*Lanx* cf. *L. undulata* (Meek). ×2. (p. 275)
14—*Physa* sp. undet. (p. 275)
15—*Pompholopsis utahensis* Yen, n. sp. ×2. (p. 275)
16a, b, c—*Pompholopsis planospiralis* Yen, n. sp. ×4. (p. 275)
17a, b, c—*Pompholopsis minima* Yen, n. sp. ×6. (p. 276)
18— *Pliopholyx reesidei* Yen, n. sp. ×1. (p. 276)
19a, b, c—*Angulorbis monocarinatus* (Chamberlin and Berry). ×4. (p. 276)
20a, b, c—*Angulorbis annectans* (Chamberlin and Berry). ×4. (p. 277)



Yen, Pliocene Freshwater Mollusks

slightly detached or barely attached to the penult whorl.

Altitude of shell	2.4 mm.
Width of shell	1.8 mm.
Diameter of aperture	1.0 mm.
Diameter of umbilicus	0.9 mm.
Number of whorls	3¼

The species resembles in outline *Valvata humeralis californica* Pilsbry, a form very widely distributed over the western States. It differs sharply by its smaller size with almost the same number of whorls, the inclination of the last part of the body whorl near the aperture, and wider umbilicus.

Holotype.—U.S.N.M. *559994;* paratypes, U.S.N.M. *559994a.*

Family Amnicolidae

FLUMINICOLA PERDITICOLLIS Pilsbry

Plate 43, fig. 5

Fluminicola perditicollis, PILSBRY, 1934, Acad. Nat. Sci. Philadelphia, Proc., vol. 86, p. 551, pl. 19, fig. 4.

Four specimens in the present collection agree well with this species, which was described from San Joaquin formation in Kettleman Hills, California, except that they are slightly narrower in outline. The largest example in the collection measures 6.8 in altitude of shell and 4.7 in width, 4.6 in height of aperture and 3.1 in width, and has 4¼ rapidly increasing whorls.

Figured specimen.—U.S.N.M. *559995.*

FLUMINICOLA YATESIANA UTAHENSIS

Yen, n. subsp.

Plate 43, fig. 6

Shell essentially similar to the typical form of this species,[1] but of smaller size, broader outline and higher spire. It has an ovate-oblong shape, and rapidly increasing and well convex whorls; it is shouldered or obtusely angulated along the periphery of the body whorl. The aperture is pyriform in outline, having a simple and continuous peristome, well defined and thickened parietal margin, and is lightly reflected at the base. Umbilicus narrowly open and somewhat excavated.

[1] Cooper, J. G., 1894; Calif. Acad. Sci., Proc. Ser. 2, vol. 4, p. 171, pl. 14, fig. 10. Pilsbry, H. A., 1934; Acad. Nat. Sci. Phila., Proc. 86, p. 553, pl. 20, fig. 14, 18–22; pl. 22, fig. 8–11.

Altitude of shell	3.0 mm.
Width of shell	2.0 mm.
Height of aperture	1.4 mm.
Width of aperture	1.0 mm.
Number of whorls	5

Holotype.—U.S.N.M. *559996;* paratypes, U.S.N.M. *559996a.*

PILSBRYUS ANTIQUUS UTAHENSIS

Yen, n. subsp.

Plate 43, fig. 7

Shell essentially similar to the typical form of the species, but differing from the species of the Idaho formation by its uniformly much smaller size in same number of whorls, narrower outline and much less calloused parietal and columellar margins. The elevation of the spire seems to be slightly variable. The following 3 examples are measured as follows (in millimeters):

Altitude of shell	9.0	8.5	8.1
Width of shell	8.1	7.2	6.6
Height of aperture	7.5	6.3	6.1
Width of aperture	5.0	5.8	4.2
Number of whorls	4¼	4¼	4

Holotype.—U.S.N.M. *559997;* paratypes, U.S.N.M. *559997a.*

PILSBRYUS cf. P. CAMPBELLI (Dall)

Plate 43, fig. 8

Lithoglyphus campbelli, DALL, 1924, U. S. Geol. Surv., Prof. Paper 132, p. 115, pl. 26, fig. 1.

A single specimen seems to be closely related to this species that was described from the Idaho formation exposed in the Snake River Valley. It seems to be characterized by its somewhat exserted spire and well rounded whorls. It measures 9.2 mm. in altitude of shell and 7.2 mm. in width, 6.4 mm. in height of aperture and 4.5 mm. in width, and has about 5 whorls.

Figured specimen.—U.S.N.M. *559998.*

Family Viviparidae

LIOPLAX UTAHENSIS Yen, n. sp.

Plate 43, fig. 9

Shell viviparoid in outline, perforately umbilicated though the perforation is sometimes entirely covered by thickening of the parietal margin. The spire is turreted and the body whorl is much inflated, the former slightly shorter than the latter. Whorls are roundly convex, rapidly increasing in size. Surface bears moderately distinct lines of

growth and occasional varix-like former lip margins. Suture well impressed. Aperture ovate in outline, having a slight notch at the posterior end; outer lip thin and simple, somewhat retreating at lower part; inner lip well thickened on the parietal margin, which sometimes completely covers the umbilical perforation. Two specimens measure:

Altitude of shell.....	14.5 mm.	15.0 mm.
Width of shell.....	11.0 mm.	11.0 mm.
Height of aperture....	8.0 mm.	8.7 mm.
Width of aperture.....	6.8 mm.	7.0 mm.
Number of whorls.....	5	5

Species of *Lioplax* have been described from Miocene beds as well as from the living fauna, but so far have not been recorded from Pliocene beds. The turreted spire, roundly convex whorls and perforate umbilicus are the common features of this genus. The present form seems to have a broader outline and more ovate aperture than any of the other species of the genus.

Holotype.—U.S.N.M. *559999;* paratypes, U.S.N.M. *559999a.*

Family Pleuroceratidae

Anculopsis Yen, n. gen.

Shell imperforate or bearing a fissure-like perforation. The umbilical area is prominently excavated and usually well marked by an angulated margin. The spire is elevated or turreted and body whorl generally dilated. Whorls rapidly increasing in size, carinated or rounded; outer lip thin and simple, retreating at its lower part; inner lip arched in the middle, generally well thickened.

Genotype—Anculopsis bicarinata Yen, n. sp.

The genus resembles *Anculosa* Say, to which it may be related. However, it is readily separated from that genus, found in the Recent fauna, by its much more pronounced anterior and posterior notches, well calloused parietal and columellar margins, as well as highly elevated spire.

Anculopsis bicarinata Yen, n. sp.
Plate 43, fig. 10

Shell angular-broadly ovate in outline, thin in substance, imperforate, having a turreted spire and ventricose body whorl; spire about one-half the altitude of the body whorl. Whorls rapidly increasing in size; first two and one-half whorls rounded and gently convex; on second half of the third whorl a faintly angular shoulder appears just below the suture, becoming prominent on later whorls, the surface above and below the carina being nearly flat or scarcely convex. The body whorl is somewhat obliquely and laterally dilated, well angulated along the periphery, and convex on the basal surface. The sculpture consists of distinct wavy lines of growth and occasional lines of former lip-margins. Aperture subovate in outline, having both posterior and anterior notches pronounced. Peristomal margin continuous; outer lip thin and simple, retreating at the lower part; inner lip well arched in the middle, well thickened, and filling part of an excavated umbilical area. Two specimens measure:

Altitude of shell.....	13.2 mm.	11.0 mm.
Width of shell.....	11.2 mm.	10.0 mm.
Height of aperture....	10.0 mm.	8.5 mm.
Width of aperture.....	7.2 mm.	6.0 mm.
Number of whorls.....	5	4¾

The species is characterized by its prominent bicarinate whorls, low but turreted spire, strong and distinct wavy growth lines. It differs from *Anculosa praerosa* Say by its strongly carinated whorls, higher spire, more pronounced apertural notches, and thickened inner lip margin. It also differs from *Anculosa carinata* Bruguiere by its more pronounced notches, prominent carinae, more thickened inner lip and retreating lower part of outer lip.

Holotype.—U.S.N.M. *560000;* paratypes, U.S.N.M. *560000a.*

Anculopsis houghterlingi Yen, n. sp.
Plate 43, fig. 11

Shell subglobosely ovate in outline, almost imperforate or bearing a fissure-like perforation, having an elevated spire, obliquely and laterally but moderately dilated body whorl; spire two-thirds altitude of the body whorl. Whorls rapidly increasing in size, particularly so in the last two whorls. Surface of the whorls rounded, gently convex, separated by an impressed suture. Sculpture consists of weak but distinct lines of growth. The body whorl is gently convex, having an angulation of the base, which defines the excavated umbilical area. Aperture

oblique, subquadrangular in outline, having both notches pronounced. Peristome continuous; outer lip thin, retreating at lower part; inner lip thickened, well arched in the middle; umbilical area partly filled by the thickening of the inner lip margin. Two specimens measure:

Altitude of shell.....	13.2 mm.	11.6 mm.
Width of shell.....	10.0 mm.	9.0 mm.
Height of aperture....	9.3 mm.	8.0 mm.
Width of aperture.....	6.7 mm.	5.8 mm.
Number of whorls.....	5	4¾

This species differs from the preceding one by absence of shoulder and peripheral carinae, more retreating lower part of outer lip margin, and more prominently excavated umbilical area.

Holotype.—U.S.N.M. *560001;* paratypes, U.S.N.M. *560001a.*

Family Ancylidae

PAYETTIA MICRA Yen, n. sp.

Plate 43, fig. 12a, b

Shell of small size and thin substance; somewhat limpet-like in outline, the body whorl nearly constituting the entire shell. The apical whorl is coiled to about two-thirds of one volution, then it is suddenly dilated into the body whorl. The aperture is ovate-oblong in outline, having its peristome thin, simple and continuous. The columellar plate is narrow and short. The holotype measures 2.0 mm. in altitude, 3.2 mm. in width and 4.5 mm. in length, having about 1½ whorls.

The species resembles *Payettia dalli* (White) in general outline, but is readily separated by its much smaller size, narrower columellar plate and less strong sculpture.

Holotype.—U.S.N.M. *560002;* paratypes, U.S.N.M. *560002a.*

Family Lancidae

LANX cf. L. UNDULATA (Meek)

Plate 43, fig. 13a, b

Ancylus undulatus, MEEK, 1870, Acad. Nat. Sci. Phila., Proc. 22, p. 57.

A number of specimens seem to be closely related, if not identical with, this species, which has been repeatedly recorded from Pliocene beds in Idaho and Nevada. The undulated sculpture of these specimens is very distinct but not very strong.

A well preserved specimen measures 4.0 mm. in altitude, 6.0 mm. in width, and 8.5 mm. in length of shell.

Figured specimen.—U.S.N.M. *560003.*

Family Physidae

PHYSA sp. undet.

Plate 43, fig. 14

A single specimen representing a young form and a few examples of apical whorls are contained in the collection, indicating the presence of *Physa* in the deposit. The young specimen has the outline of *Physa humerosa* Gould, but it is too imperfect for specific identification.

Figured specimen.—U.S.N.M. *560004.*

Family Planorbidae

POMPHOLOPSIS UTAHENSIS Yen, n. sp.

Plate 43, fig. 15

Shell subglobose in outline, deeply and openly umbilicated, having a low and small spire and ventricose body whorl. Whorls increasing very rapidly in size, gently convex; apical whorl slightly elevated and glossy smooth; last 2 whorls with distinct riblines and growth striae. Suture well impressed. Body whorl greatly dilated, very obtusely angulated or almost rounded at the periphery, reduced towards the base. Aperture pyriform in outline; peristome continuous, thin and simple; inner lip margin slightly curved. Two specimens measure:

Altitude of shell.....	6.6 mm.	6.1 mm.
Width of shell.....	7.8 mm.	6.9 mm.
Height of aperture.....	6.0 mm.	5.0 mm.
Width of aperture.....	5.0 mm.	4.5 mm.
Number of whorls.....	3	3

The species differs from *Pompholopsis whitei* Call (Amer. Geol., 1888, vol. 1 (3), p. 147) by its smaller size, much lower spire, distinct growth striae and strong riblines. The elevation of the spire varies slightly in this species, but it is never so highly elevated as in *P. whitei.*

Holotype.—U.S.N.M. *560005;* paratypes, U.S.N.M. *560005a*

POMPHOLOPSIS PLANOSPIRALIS Yen, n. sp.

Plate 43, fig. 16a, b, c

Shell ovately planorboid in outline, of thin substance, openly umbilicated, having a nearly flat, depressed spire and laterally

dilated body whorl. Whorls increasing very rapidly in size, apical whorl very small and smooth, and following whorls bearing strong riblines on the surface. Suture well impressed. Body whorl almost rounded at the periphery and convex at the base. Aperture roundly ovate in outline; peristome simple and continuous; parietal wall barely attached to the preceding whorl; columellar margin short and oblique, slightly reflected at upper part and covering part of the umbilicus. Two specimens measure:

Altitude of shell	3.5 mm.	2.7 mm.
Width of shell	5.0 mm.	4.2 mm.
Height of aperture	2.2 mm.	2.1 mm.
Width of aperture	2.6 mm.	2.5 mm.
Number of whorls	2¾	2¼

This species differs from the preceding one by its more planorboid outline, almost flattened spire, roundly ovate aperture and stronger sculpture.

This and the preceding species bear resemblance to forms of *Parapholyx* Hanna, a genus known from Pliocene to Recent times. However, these species are more or less deeply and openly umbilicated and have a much less thickened inner lip. None of the known species of *Parapholyx* is truly umbilicated.

Holotype.—U.S.N.M. *560006;* paratypes, U.S.N.M. *560006a.*

POMPHOLOPSIS MINIMA Yen, n. sp.
Plate 43, fig. 17a, b, c

Shell of small size, thin substance; ovately planorboid in outline; openly umbilicated; having a small, low but elevated spire, and laterally inflated body whorl. Whorls increasing very rapidly in size; apical whorl very small, rising above subsequent whorls. Whorl surface scarcely convex, bearing fine lines of growth, rounded along the periphery of the body whorl. Aperture transversely ovate in outline, somewhat descending, having its peristome continuous; outer lip thin; inner lip moderately thickened; parietal wall barely attached to the penultimate whorl; columellar margin short and covering part of the umbilical opening.

Altitude of shell	2.6 mm.
Width of shell	3.0 mm.
Height of aperture	1.2 mm.
Width of aperture	1.8 mm.
Number of whorls	2¾

A single and apparently mature specimen is contained in the collection. It clearly bears the features of the genus; however, it is different from *P. whitei* and the preceding 2 species in size, general contour of the shell and sculpture. It resembles somewhat *Acrobis petricola* Odhner, a monotype species described from Brazil, but there is not sufficient basic information in regard to its shell variation and habitat condition to suggest the relationship of the present species to the South American form.

Holotype.—U.S.N.M. *560007.*

PLIOPHOLYX REESIDEI Yen, n. sp.
Plate 43, fig. 18

Shell globose in outline with a low spire and ventricose body whorl. Whorls increasing rapidly in size, bearing distinct growth lines. The early whorls are gently convex and the last 2 are well shouldered near the suture. The body whorl constitutes nearly the entire shell, rounded at the periphery. The aperture is ovate in outline, having a slight notch produced posteriorly near the suture and anteriorly on the basal margin. The peristome is continuous, having outer lip thin and sharp, retreating at its lower part, inner lip well thickened. The umbilicus is narrowly rimate, having an excavated area produced below the fissure-like opening and this area is well defined by a sharp, marginal line. Two specimens measure:

Altitude of shell	17.0 mm.	16.2 mm.
Width of shell	15.1 mm.	15.0 mm.
Height of aperture	14.1 mm.	13.2 mm.
Width of aperture	9.0 mm.	8.9 mm.
Number of whorls	5	5

This species differs from *Pliopholyx idahoensis* Yen by its low spire, larger size in less number of whorls, better developed apertural notches and characteristic umbilicus.

Holotype.—U.S.N.M. *560008;* paratypes, U.S.N.M. *560009.*

ANGULORBIS MONOCARINATUS (Chamberlin and Berry)
Plate 43, fig. 19a, b, c

Gyraulus monocarinatus, CHAMBERLIN and BERRY, 1933, Nautilus, vol. 47 (1) p. 27, pl. 5, fig. 7, 8.

A number of examples in the collection seem to agree well with this species, de-

scribed from an outcrop near Colliston, Utah, except that some of the specimens here bear a stronger carina encircling the umbilicus and others a much weaker ridge on the basal surface. This basal carina is not mentioned in the original description of the species, though it may be weakly developed.

This species seems to belong to *Angulorbis* Yen, a genus proposed for the carinated species, with more or less perspective umbilicus, of *Gyraulus*-like planorbids found in the Pliocene beds. It differs from *Angulorbis multicarinatus* Yen by its larger size, more rapidly increasing whorls, roundly convex base, simple sculpture and narrower umbilicus.

Figured specimen.—U.S.N.M. *560010.*

ANGULORBIS ANNECTANS
(Chamberlin and Berry)
Plate 43, fig. 20a; b, c

Gyraulus annectans, CHAMBERLIN and BERRY, 1933, Nautilus, vol. 47 (1) p. 27, pl. 5, fig. 9, 10.

There are six examples representing this species in the collection. Its generic assignment is considered provisional. This species seems to resemble the preceding species more closely than any species of *Gyraulus* known to me. Its body whorl is rather weakly angulated along the periphery, decidedly not rounded. The basal carina around the umbilicus is well developed.

As in the deposit exposed near Collinston, Utah, the present form is found in association with the preceding species in the present collection.

Figured specimen.—U.S.N.M. *560011.*

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BIBLIOGRAPHY OF FORAMINIFERA (SUPPLEMENTS FOR 1940 TO 1945)

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IN ORDER to make known more rapidly the titles of papers dealing partly or wholly with Foraminifera, which appeared in print outside the United States during the war years, a supplementary list for the years 1940 to 1945 inclusive is herewith given. For the literature of this period on Foraminifera reference is made to the bibliographies published in this JOURNAL, vol. 17, 1943, pp. 388–408 for the year 1940; vol. 18, 1944, pp. 387–404 for the year 1941; vol. 19, 1945, pp. 396–410 for the year 1942; and pp. 648–656 for the year 1943; vol. 20, 1946, pp. 172–183 for the year 1944, and pp. 591–619 for the year 1945.

Seven titles are added for the year 1940, bringing the total of foraminiferal literature for that year up to 263 numbers; 6 are supplemented for the year 1941 (total up to date: 266 papers); 19 refer to the year 1942 (total so far: 236 papers); 16 belong to the year 1943 (total to date: 210 papers); 9 were published during 1944 (total: 167 papers) and 26 titles are furnished for 1945, making a total of 203 for this year.

There is still a lack of information regarding foraminiferal literature published since 1939–40 in Soviet Russia and the Eastern countries of Europe. The compiler emphatically urges those scientists who have the opportunity of filling this gap to publish a list of papers and an index to the new forms of Foraminifera without delay.

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COBBOLD, EDGAR STERLING. Died Nov. 20, 1936.
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NOMINATIONS FOR OFFICES IN THE PALEONTOLOGICAL SOCIETY FOR 1948

In accordance with the provisions of Chapter IV, Section 1, of the By-Laws, the Council of The Paleontological Society announces the following nominations for offices in the Society for 1948:

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PALEONTOLOGICAL NOTES

NOTE ON "PALEOECOLOGICAL IMPORT OF SALINITY"

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In the JOURNAL for January 1947 (21.1: 77–79) is a short paper by Gordon Gunter: "Paleoecological import of certain relationships of marine animals to salinity," which is an example of a type of paper which paleontologists need and which the JOURNAL should actively encourage. A great deal of work is being done in oceanography and marine ecology with which we know we should be familiar, but life is short. Such contributions by biologists, interpreting their findings, are to be welcomed.

I think, however, that in seeking brevity and simplicity Gunter has left an incorrect impression of the importance of salinity changes in controlling animal distributions, especially those animals preserved as fossils. Situations where pronounced disparities in salinity exist are very rare, apart from estuaries, and are usually quite temporary. Still, locally the densities do vary, and it is well to have this in mind, especially when dealing with faunas which lived in epicontinental seas where subestuarine conditions might be postulated.

This note arises from what I feel is the undue emphasis of Gunter's two summarizing statements: "If a paleontologist working along a marine horizon finds that the number of species of animals increases" and "if a paleontologist finds that the average size of fossil animals increases" then in both cases "it is strong evidence that he is following a salinity gradient." If both conditions are present they "might be conclusive." This I suggest, is most misleading.

If the variety of species and the size of individuals increases, then the simple and obvious interpretation is that one is approaching shore. Unless there are other strong evidences that salinity differences are involved, I do not think that these criteria can be considered to suggest such an explanation.

Most of the paleontological lateral variations are due to local differences in bottom conditions, which are reflected not only in the benthos but also in the predatory nekton associated with it. In this connection the work of Petersen is most suggestive, especially his paper of 1918, from which some illustrations have been copied in the more accessible work of Hesse et al. (1937, pp. 191–194).

Certain large scale trends are well established, and should be familiar to those trying to interpret fossil faunas. In contrast to the rarity of salinity gradients, those in temperature are numerous and far reaching in their effects. Warm waters have a greater variety of genera and species, but fewer individuals, than colder waters. In cold water animals frequently grow to sizes abnormally large for their species or genus, and occur in great numbers. Hesse (p. 275) gives, after Lohmann, as a rough example the count of an average 2,500 organisms from 1 liter of cold water, and only 700 in water above 20°C. This gradient shows itself in various ways, and different animals are affected differently by it. Thus in teleosts there is an increase in the number of vertebrae in cold water (Hesse, p. 159). Solitary and aggregate salps differ in their temperature preferences, with the former preferring the colder water (Pearse 1926, p. 165, after Michael). The ability to use lime drops sharply with a fall in temperature, and we find that animals which have heavy shells in tropical waters are naked or very thinly shelled in the Arctic (Hesse, p. 157 ff.). Thus in a gradient from warm to cold water we would expect to find our total population increasing, its variety declining, the size of the individuals increasing, and their calcareous parts if any diminishing.

Possibly the most striking gradational change is that from the open ocean to the sublittoral waters, although the causes are so complex and interrelated that analysis is not simple. Nowhere is there such a variety of animal life as in the sublittoral zone, where the water is shallow enough to allow good illumination, there is an abundance of or-

ganic mud to support a large benthos, and sufficient agitation of water to provide aeration and to keep minute food particles in suspension. The variety of animals falls off both as the beach is approached and as one moves into the open ocean. With the latter shift one also finds that the size of the individuals decreases. Murray and Hjort (1912) say: "For unicellular plants as well as for animals, the rule holds good that all forms are much larger (in waters of less than 150 meters depth) than those of the open ocean" (Quoted from Pearse, p. 166). So that in moving from an open ocean to a sublittoral environment we would expect to find our fauna more varied, the individuals more abundant and larger.

These are two general trends, and only a detailed report could include the individual qualifications necessary for a proper rounding of the picture. I have made no attempt here to go back to sources, quoting instead from texts at hand, as I wish simply to draw attention to other gradients which may produce the same effects of a fauna as would a salinity gradient. With these other possible factors in mind Gunter's notes are most useful.

MANUSCRIPT RECEIVED JANUARY 31, 1947.

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REVIEW

REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY, 1945–46. National Research Council, Division of Geology and Geography, Washington, D. C. Dated Dec., 1946. Pp. 101; 1 text fig. Price, $0.50.

This mimeographed report, the sixth issued by the committee, contains a number of features which will be of interest to all paleontologists, Chief among these is the outline of a proposed "Treatise on Marine Ecology and Paleoecology," to be prepared by the committee with the aid of interested specialists. This outline is published as a tentative framework for the treatise, and suggestions for its improvement, as well as volunteers in the actual writing of the treatise, are solicited.

Current activity in ecological study is reported in 18 pages of project notes and annotated bibliography. Forty recent Japanese papers in this field are abstracted, some at considerable length, and an annotated bibliography on Pacific marine invertebrate ecology occupies 16 pages.

Six signed contributions on specific ecological studies conclude the report. They represent well the present state of our knowledge in this field. Five of these papers describe techniques for study, or report on observed data, drawing few general conclusions. Only the sixth paper (The Life and Environment of the Early Ordovician Sea in Central Texas, by P. E. Cloud, Jr., and V.E. Barnes) gives any extended analysis and interpretation of paleoecologic conditions.

The large amount of ecological work summarized in this report will steadily advance the frontier of our knowledge along these lines. To the reviewer, however, this report suggests that more general and useful conclusions might be drawn from complete and concentrated study of a few unusually favorable areas. The Texas studies of Cloud and Barnes, and the Permian studies under way at the Smithsonian Institution are examples. We need an agency to receive reports of environmental type areas exceptionally well suited to thorough study and analysis. This agency could then choose the best of such areas and concentrate upon them a coordinated research program, both qualitative and quantitative in nature. When not only the paleontologists but the petrologists as well have mined all the data from such a spot their resulting conclusions should be of maximum use to others.

A. SCOTT WARTHIN

JOURNAL OF PALEONTOLOGY, VOL. 21, NO. 3, P. 296, MAY 1947

NOMENCLATURAL NOTES

INCORPORATION OF THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE

The following notice was recently received from Mr. Francis Hemming, Secretary to the International Commission on Zoological Nomenclature:

In view of the increasing volume and complexity of their work, the International Commission on Zoological Nomenclature have reached the conclusion that the time has come when it is essential to bring into existence an incorporate body which, under the general directions of the Commission, will be responsible for the conduct of the Commission's business affairs.

The formalities necessary to give effect to this decision have now been completed and the International Commission have pleasure in announcing the establishment of the "International Trust for Zoological Nomenclature." The members of the Commission are members of the Trust. The Secretary to the Commission has been appointed Secretary of the Trust. The office of the Trust will be at the same address as that of the Commission.

The Trust is now responsible for financing the Commission's publications and all cheques and other drafts in payment for copies of the Commission's publications should in future be drawn in favour of the International Trust for Zoological Nomenclature.

RECENT PUBLICATIONS OF THE INTERNATIONAL COMMISSION ON ZOOLOGICAL NOMENCLATURE

The following publications were issued March 3, 1947:

OPINIONS

Part 22.—Opinion 13.—The specific name of the Sand Crab. With 2 plates. Price 6s. 11d.

Part 23.—Opinion 14.—The type species of *Etheostoma* Rafinesque, 1819 (class Pisces, order Percomorphi). Price 2s. 1d.

Part 24.—Opinion 15.—*Craspedacusta sowerbii* Lankaster, 1880, n. g., n. sp. versus *Limnocodium victoria* Allman, 1880, n. g., n. sp., a freshwater medusa (class Hydrozoa, order Trachymedusae). Price 2s. 1d.

Part 25.—Opinion 16.—The status, under rule (d) in Article 30, of pre-binomial specific names (published prior to 1758) in relation to a generic name published on, or before 31st December, 1930. Price 8s. 5d.

Part 51.—Opinion 181.—On the type of the genus *Carcharodus* Hubner, (1819) and its synonym *Spilothyrus* Duponchel, 1835 (class Insecta, order Lepidoptera), genera based upon erroneously determined species. Price 4s. 10d.

Part 12.—Opinion 193.—On the status of the name *Procheneosaurus* Matthew, 1920 (class Reptilia, order Ornithischia). Price 2s. 10d.

Part 13.—Opinion 194.—On the status of the name *Ophiceras* Griesbach, 1880 (class Cephalopoda, order Ammonoidea). Price 2s. 10d.

BULLETIN OF ZOOLOGICAL NOMENCLATURE

Vol. 1, Part 9. Price 5s. 7d.

Vol. 1, Part 10. Price 5s. 7d.

Vol. 1, Part 11 (issued March 31, 1947). Price 5s. 7d.

Remittances, to the order of the Trust, payable in pounds sterling in London, should be sent to the Commission at 41 Queen's Gate, London S. W. 7, England.

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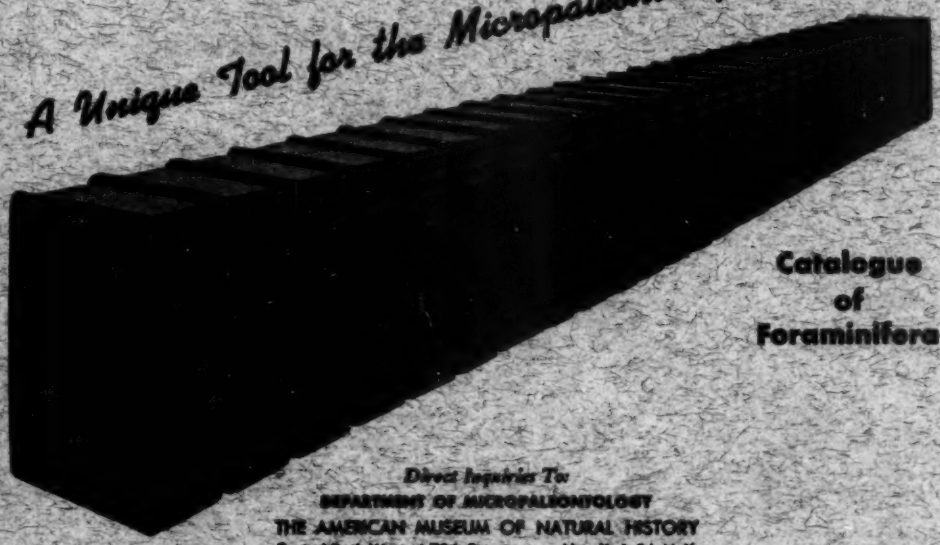

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